Prepared in cooperation with the Nottawaseppi Huron Band of Potawatomi Indians

Water Resources on and near the Nottawaseppi Huron Band of Potawatomi Indian Tribal Lands, Calhoun County, Michigan, 2000-03

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By T.L. Weaver, D. Healy, and T.G. Sabin

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U.S. Department of the Interior
Gale A. Norton, Secretary

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Hydraulic conductivity	
gallons per day per foot squared [($gal/d/ft^2$)]	40.7	liter per day per squared meter [$(L/d)m^2$]
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Altitude, as used in this report, refers to distance above the NGVD 29.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L), micrograms per liter (µg/L), or nanograms per liter (ng/L). For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Water Resources on and near the Nottawaseppi Huron Band of Potawatomi Indian Tribal Lands, Calhoun County, Michigan, 2000-03

By T.L. Weaver, D. Healy, and T.G. Sabin

ABSTRACT

The Nottawaseppi Huron Band of Potawatomi Indians in Calhoun County, Michigan is concerned about the water quality and quantity of streams in and around tribal lands and of shallow ground water. The tribe wanted to establish a database that included streamflow, stage, and water quality of local streams and quality of ground water from wells belonging to the tribe and its members. Concerned about the effects of long-term agricultural activity and increasing numbers of single-family dwellings being constructed within the watershed both on and off the reservation, the tribe wants to develop a water-resources management plan.

U.S. Geological Survey (USGS) measured streamflow and installed staff gages tied into local datum on three tributaries of the St. Joseph River that cross tribal lands. Water-quality samples were collected from the sites under a variety of flow regimes from spring to fall during 2000-03. Stage-streamflow rating curves were constructed for Pine Creek and Athens & Indian Creek Drain after a number of discharge measurements were made and a thorough basin analysis was completed. Daily streamflow for Pine Creek near Athens was estimated for the period from May 2000 through September 2003.

USGS collected 12 water samples at Pine Creek near Athens, Athens & Indian Creek Drain, and an unnamed tributary to Pine Creek during October 2000 through September 2003. Physical properties were measured, and the streams were sampled for major ions, nutrients, trace elements, caffeine, and herbicides/pesticides and their breakdown products (degradates). The tribe also measured physical properties weekly at the three sites during each growing season for the study period. Surface water at the three sites can be classified as hard, with calcium carbonate concentrations exceeding 180 milligrams per liter (mg/L). Concentrations of calcium, magnesium, chloride, and dissolved solids are typical of the area. There were 68 detections of 17 pesticides, degradates, and caffeine. Atrazine and metolachlor were detected in all samples, and the atrazine degradate deethylatrazine was detected in all samples from Pine Creek and Athens & Indian Creek Drain. Another atrazine degradate (2-hydroxy-atrazine, or OIET) was detected five of the six times that it was included in the analyses. A single sample collected from Athens & Indian Creek Drain in May 2001 had relatively higher concentrations of acetochlor, atrazine, CIAT (deethylatrazine), and diuron than the other sampling sites did during the study. Analysis for various species of mercury was completed on samples collected at Pine Creek and Athens & Indian Creek Drain in July 2003, and results were similar to those typical of unimpaired streams in the Midwest. None of the surface-water sites had major ion, nutrient, or trace-element concentrations that exceeded Michigan Department of Environmental Quality standards for nonpotable surface water.

USGS also collected 11 ground-water samples from 7 wells on or adjacent to the traditional reservation in 2003. Two wells were sampled twice, and a single well was sampled three times, in order to document any chemical changes that might have occurred as a result of aquifer recharge, which most typically occurs in late winter to spring in the southern Lower Peninsula of Michigan. Samples were analyzed for 184 pesticides and degradates and caffeine. There were five detections of four pesticides or degradates, but none of the detected chemicals are included in current U.S. Environmental Protection Agency drinking-water standards. The remaining 181 analytes were below laboratory reporting limits.

INTRODUCTION

The Nottawaseppi Huron Band of Potawatomi Indians (NHBP), whose reservation is near the Village of Athens in south-central Lower Michigan, is concerned about the quality and quantity of water in area streams

and of shallow ground water (fig. 1). The tribe recognizes that Pine Creek and its associated tributaries provide an appreciable resource for maintaining subsistence needs for tribal members. Agricultural activities including livestock rearing and corn and soybean production are common in the watershed where the reservation is located. The water-quality and -quantity effects of crop irrigation withdrawals, pesticide applications, agricultural runoff, and increasing numbers of single-family dwellings with private wells and septic systems in and near the reservation are unknown.

The NHBP Reservation lies entirely within the St. Joseph River Basin, which drains to Lake Michigan (fig. 1). Four tributaries of Pine Creek or Nottawa Creek are near the reservation. The tributaries are Pine Creek, with headwaters north of the reservation; a county drain locally known as Athens & Indian Creek Drain, which drains farmland northwest of the reservation; another county drain locally known as Schneider & Schneider Extension Drain (Sherry Trader, Calhoun County Drain Commission, written commun., 2003) just south of the reservation; and an unnamed creek that flows from the west into Pine Creek after crossing the Fuller Property about 1.5 mi north of the reservation.

There are no known studies of geology or hydrology of the area near the reservation; however, a wellhead protection area (WHPA) delineation was completed as part of the Village of Athens wellhead protection plan (Fleis and Vandenbrink Engineering, 2000), and a ground-water investigation was completed for the House of Raeford Farms. The House of Raeford Farms is southwest of Athens and is referenced in the Athens WHPA delineation. U.S. Geological Survey (USGS) also studied agricultural land use and water quality in the upper St. Joseph River Basin (Cummings, 1978); but that part of the St. Joseph River Basin is south and east of the current study area. Additionally, USGS operated a continuous-record streamflow-gaging station about 5.5 mi downstream from the reservation on Nottawa Creek during 1967-97 (Blumer and others, 1998), and various other continuous-record streamflow-gaging stations within 20 mi of the reservation.

Implementing a comprehensive water-resources plan that protects tribal water resources could not be completed until baseline water-quality data were collected and analyzed, and surface- and ground-water measurements made and compiled. The investigation described in this report was a cooperative effort between NHBP and USGS. The U.S. Environmental Protection Agency (USEPA) and Bureau of Indian Affairs (BIA) provided assistance to NHBP for the study.

Purpose and Scope

This report describes the physical and chemical characteristics of surface- and ground-water resources of NHBP, and relates these attributes to geology, hydrology, and land use. The report is based on surface-water quality and flow data and ground-water quality data that were collected by USGS and NHBP Tribal staff during 2000-03. The study provides information that will assist the tribe in devising strategies for resource management, including water-quality protection and water-supply development.

Methods of Investigation

In 2000, USGS and tribal environmental staff prepared a Quality Assurance Program Plan (QAPP) that was reviewed and accepted by USEPA Region 5 before data collection was started. All aspects of the study followed procedures and guidelines identified in the QAPP. Physical properties were measured and water-quality samples were collected and processed in accordance with procedures established in the USGS "National Field Manual for the Collection of Water-Quality Data" (Wilde and others, 1998). All water-quality samples were analyzed at the USGS National Water-Quality Laboratory and documented in accordance with procedures and guidelines identified in the QAPP.

In 2000 and 2001, the study focused on evaluating water quality and measuring streamflow (discharge) of three streams crossing the reservation. The unnamed tributary to Pine Creek northwest of the traditional reservation was sampled once, Athens & Indian Creek Drain was sampled twice, and Pine Creek was sampled three times during this period. Water-quality samples were collected at different times during the growing season. Initial sampling was completed in October 2000, coinciding with a period of little, if any, runoff and low streamflow, maximum terrestrial vegetation growth, and minimal pesticide use. The April 2001 sampling coincided with a period of maximum runoff and minimal pesticide use, whereas the late-May 2001 sampling coincided with a period of emergent vegetation growth, maximum application of pre-emergent pesticides, and relatively greater streamflow resulting from late-spring precipitation. Physical properties were measured in situ and included water temperature, pH, specific conductance, and dissolved-oxygen concentration. Water-quality samples were collected and analyzed for major ions, trace elements, nutrients, and a suite of agricultural pesticides.

In 2002, the study concentrated on investigation and analysis of ground water in the aquifer closest to land surface and continued streamflow measurements at sites including Nottawa Creek downstream from the conflu-

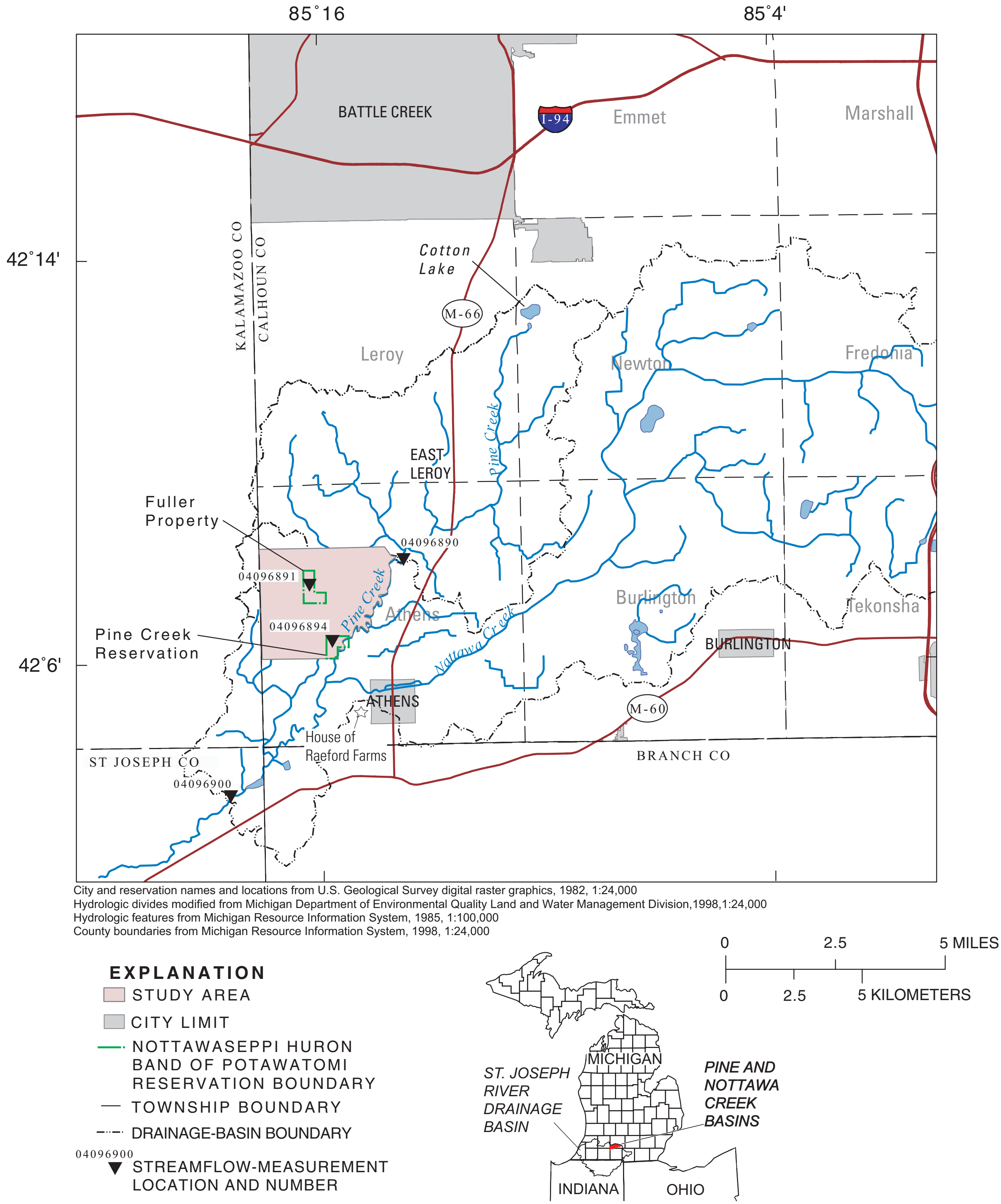


Figure 1. Location of study area and Nottawaseppi Huron Band of Potawatomi Indian (NHBP) Tribal properties, Calhoun County, Michigan.

ence with Pine Creek. A review of the City of Athens WHPA delineation (Fleis and Vandenbrink Engineering, 2000) was also completed to determine the applicability of aquifer characteristics from the WHPA to the aquifer underlying the reservation.

In 2003, the investigation of pesticide concentrations in Pine Creek and Athens & Indian Creek Drain was intensified; one complete water-quality sample collected at each site, including pesticides and their breakdown products (degradates), and four additional samples were analyzed only for pesticides and their degradates. This part of the study documented changes in pesticide concentrations in the streams during an entire growing season, from April to September 2003. The tribal center well and six domestic-supply wells belonging to tribal members were sampled for pesticides in 2003. Two of the domestic-supply wells were sampled two times, and a single well was sampled a third time, to document any change in pesticide concentrations during the year as a result of aquifer recharge. Streamflow measurements were made routinely at Nottawa and Pine Creeks, and Athens & Indian Creek Drain throughout 2003 for purposes of developing a basin-basin relation, in addition to supporting loading calculations.

GENERAL DESCRIPTION OF STUDY AREA

The NHBP Pine Creek Reservation is in Athens Township in the southwestern corner of Calhoun County in Michigan's Lower Peninsula (fig. 1). During the 2000 Census, Athens Township had a population of 2,571. The study area, which comprises about 6.5 mi^2, includes the traditional reservation along Pine Creek, consisting of about 120 acres; a 155-acre site northwest of the traditional reservation known as the Fuller Property; and the general area surrounding the tribal properties and west of Pine Creek (fig. 2). The land surface is flat-lying, except near the stream channels and at widely scattered glacial hills, and ranges in altitude from 860 to 930 ft. The study area boundaries are O Drive South on the north and T Drive South on the south, Pine Creek on the east, and the Calhoun County line on the west. Most land within the study area as well as the Nottawa Creek watershed is agricultural, although large parts are mostly forested or wetland (fig. 3). Land use in the study area in the study area is summarized in table 1. No cities are within the study area, although the Village of Athens is 2 mi southeast of the traditional reservation and Battle Creek is 12 mi north.

Climate is typical of the southern Lower Peninsula of Michigan. The region receives an average of about 33 to 34 in. of precipitation a year (Vanlier, 1966; Mark Walton, National Oceanic and Atmospheric Administration, written. commun., 2001). Of this amount, about two-thirds is returned to the atmosphere by evaporation and transpiration from plants. The remaining third moves to streams by direct runoff or infiltrates or percolates into the ground and moves to the streams by underground flow. Current 30-year mean monthly air temperatures in Battle Creek range from 23^{o}F in January to 72^{o}F in July (Mark Walton, National Oceanic and Atmospheric Administration, written. commun., 2004). Similar temperatures are typical in the study area.

GEOLOGIC SETTING

The near-surface geology of the NHBP Reservation consists of unconsolidated Holocene and Pleistocene alluvial deposits and Pleistocene glaciofluvial deposits, underlain by Mississippian Coldwater Shale. General lithologic characteristics are described in the following sections. Specific lithologic information is included in the appendix, which contains drillers' logs of public-water-supply (PWS) wells and test wells drilled for the tribe. Additional lithologic information can also be found on drillers' logs of domestic-supply wells, which are available at Calhoun County Health Department and Michigan Department of Environmental Quality (MDEQ). Thickness of unconsolidated deposits varies considerably across the study area, with thickest deposits near stream courses. Drillers' logs of wells indicate that the Coldwater Shale, or broken and fractured pieces of the Coldwater Shale, can be found as close as 23 ft below the surface, whereas unconsolidated deposits as thick as 200 ft are found near Nottawa Creek (Fleis and Vandenbrink Engineering, 2000). Unconsolidated deposits are typically in the range of 50 to 85 ft thick near the reservation.

Alluvial Deposits

Alluvial deposits in the study area are typical of those found throughout southern Michigan, consisting of muck, clay, silt, sand, and gravel. Pine Creek is in

Table 1. Land use in the study area, Calhoun County, Michigan. Numerical values in the table are rounded.

Land-cover type	Percentage of study area
Agricultural	64.8
Forested upland	20.4
Wetland	14.4
Barren cover	0.35
Developed	.05
Water	.01

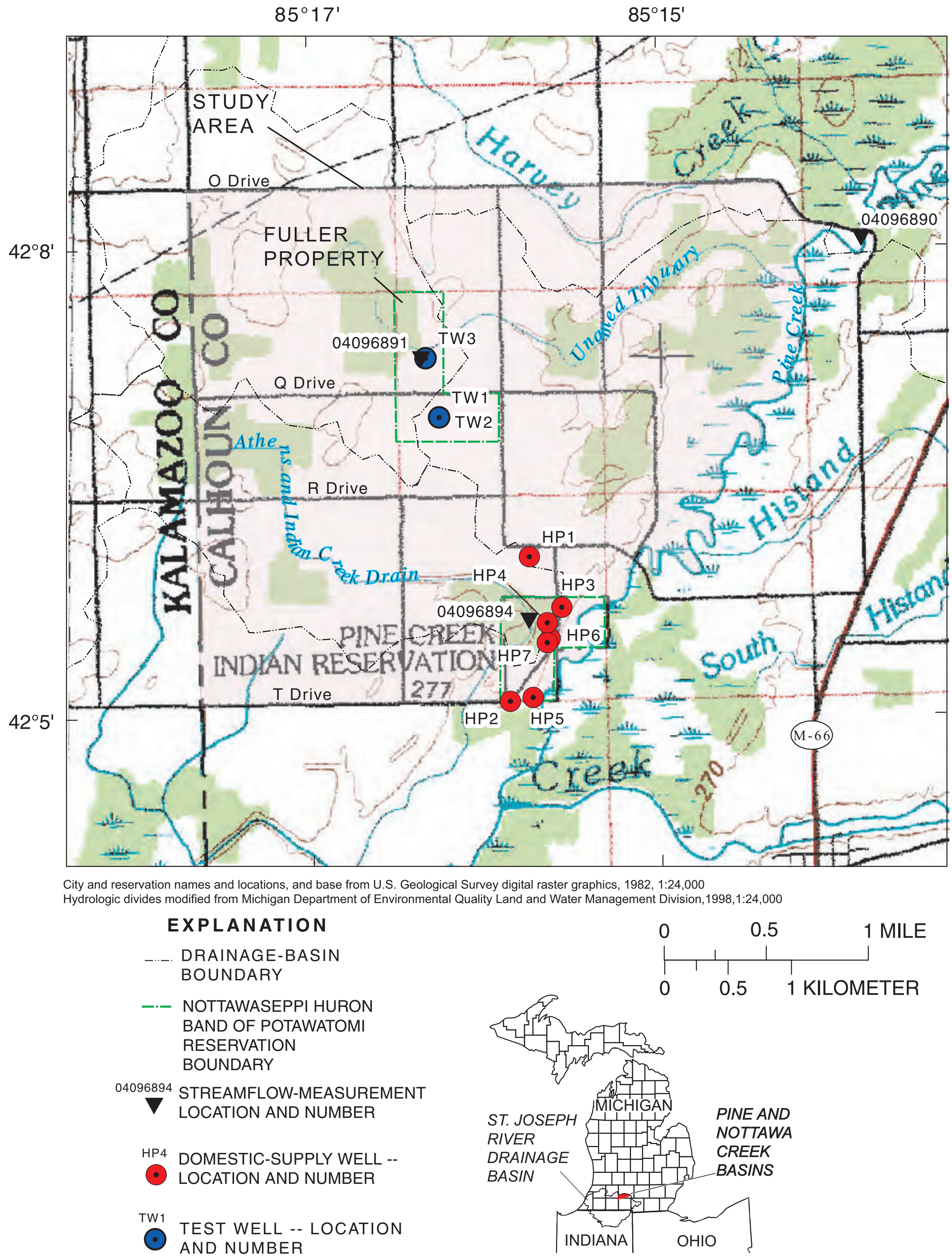


Figure 2. Location of ground-water and surface-water sampling locations, Calhoun County, Michigan.

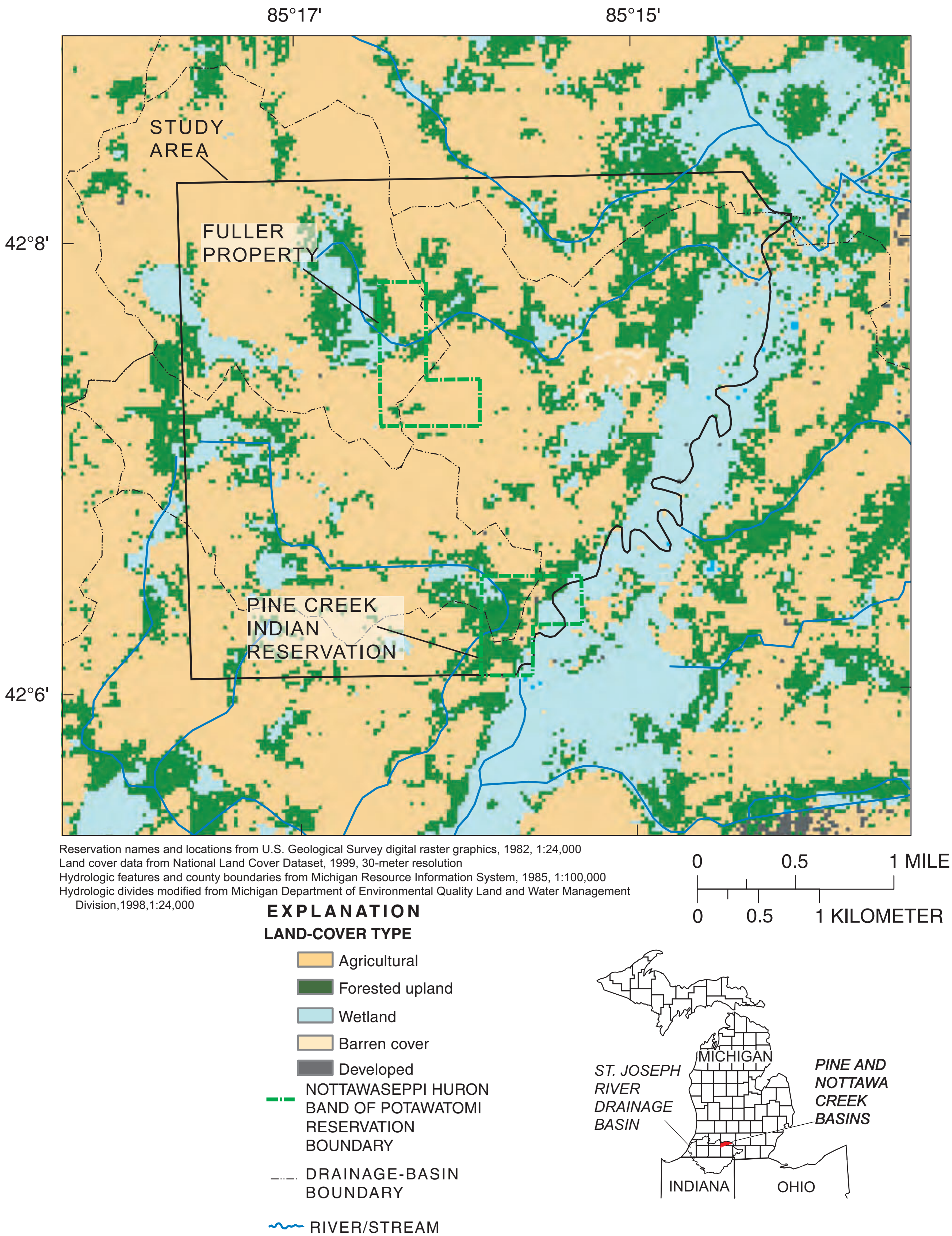


Figure 3. Distribution of land-cover types within the study area, Calhoun County, Michigan.

backwater along much of the boundary with the NHBP Reservation, and deposits in that area are commonly associated with a wetland environment. Alluvial deposits often comprise reworked glacial deposits in addition to more modern deposits of geologic (soils) and organic origin.

Glacial Deposits

During the Wisconsinan stage of Pleistocene continental glaciation, the Lower Peninsula of Michigan was covered by ice multiple times (Dorr and Eschmann, 1970) with periods of retreat (wastage) followed by readvances of the ice sheets. The Saginaw lobe covered much of the Lower Peninsula, bounded on the west by the Lake Michigan lobe and on the east by the Huron-Erie lobe (Martin, 1958). The Lake Michigan lobe was probably thin and overrode previously deposited sands and gravels in eastern Kalamazoo and western Calhoun Counties (Martin, 1958). Retreat of the Lake Michigan lobe probably occurred slowly, forming till plain in eastern Kalamazoo and western Calhoun Counties (Rheaume, 1990). Although previous Pleistocene ice sheets had advanced considerably south into Ohio and Indiana, the final advance of the Saginaw lobe stopped 5-10 mi north of the NHBP Reservation. The southernmost position of the Saginaw lobe is marked by the Tekonsha moraine, which crosses Michigan Highway 66 just north of East Leroy, trending slightly northwest across Calhoun County, from Tekonsha toward Climax in Kalamazoo County (Farrand and Bell, 1982; Monaghan and Larson, 1982) (fig. 4). The outwash plains and channels south of the Tekonsha moraine, including the Pine Creek channel, were deposited during the wastage of the Michigan lobe at the Tekonsha morainal position.

In the study area, glacial deposits are diverse, having been laid down in more than one depositional environment (fig. 4). The lithology of the deposits is documented in drillers' logs from the study area. Deposits in the immediate vicinity of the Pine Creek channel and to the east are mapped by Farrand and Bell (1982) as outwash deposits, comprising clay to cobble-sized particles, with coarser materials close to the historic and present stream channel(s), and becoming finer with distance from the channel(s). Sorting of outwash deposits typically ranges from poorly sorted to well sorted, with cross-bedding frequently evident. The area west of Pine Creek is mapped by Farrand and Bell (1982) as medium-textured till, with a silty loam to loam texture composing the matrix, and particle sizes ranging from clay to cobble. Monaghan and Larson (1982) interpreted the area west of Pine Creek as a till plain. Drumlins are common features on the till plain just west of the reservation.

Farrand and Bell (1982) mapped the materials near Pine and Nottawa Creeks as glacial outwash sand and gravel and postglacial alluvium, with some Holocene alluvium in most places as well. Glacial deposits unconformably overlie rock of the Coldwater Shale throughout the study area. The unconformity in the study area is present where all younger bedrock units including younger Mississippian, Pennsylvanian, and Jurassic Formations have been eroded off, leaving the Coldwater Shale as the youngest and stratigraphically highest bedrock unit present.

Headwaters of Pine Creek are about 7 mi north of the traditional reservation in the Tekonsha moraine. Headwaters of both unnamed tributaries to Pine Creek in the study area are in the till plain northwest of the traditional reservation.

Bedrock

The Mississippian Coldwater Shale is the uppermost bedrock unit underlying the study area (Milstein, 1987). The Coldwater Shale is primarily gray to dark gray shale, but it includes some red shale, carbonate, siltstone, and sandstone (Cohee, 1979; Hale, 1941; Monnett, 1948). Total thickness of the Coldwater Shale ranges from 500 ft in the western part of the Michigan Basin (fig. 5)(Cohee, 1979) to 1,300 ft in the east (John Esch, Michigan Department of Natural Resources, written commun., 1994). The source area for the Coldwater Shale is inferred to be in southwestern Ontario (Potter and Pryor, 1961). The unit typically consists of coarser grained materials as it thickens to the east. John Esch (Michigan Department of Environmental Quality, oral commun., 2004) noted that the Coldwater Shale is about 700 to 800 ft thick in southwestern Calhoun County. Sandstone and other coarse-grained beds within the Coldwater Shale are common in the Thumb Area of Michigan (fig. 5), where they range in thickness from 223 to 275 ft (Cohee, 1979); however, they are largely absent in most of the Coldwater's western extent.

Depth to the Coldwater Shale is known from drillers' logs of a few wells in, or adjacent to, the study area. Depth to the Coldwater Shale in those logs is variable, ranging from 46 to 85 ft. Two of the Village of Athens PWS wells are 125 and 130 ft deep, respectively, and neither reached bedrock. As is typical with most places in the Midwest, the greatest depth to bedrock coincides with the larger preglacial drainageways, such as Nottawa and Pine Creeks. An extensive bibliography of available studies of the Coldwater Shale is included in Westjohn and Weaver (1998).

HYDROGEOLOGY

Unconsolidated glacial deposits are thought to be the sole source of potable water available to the NHBP

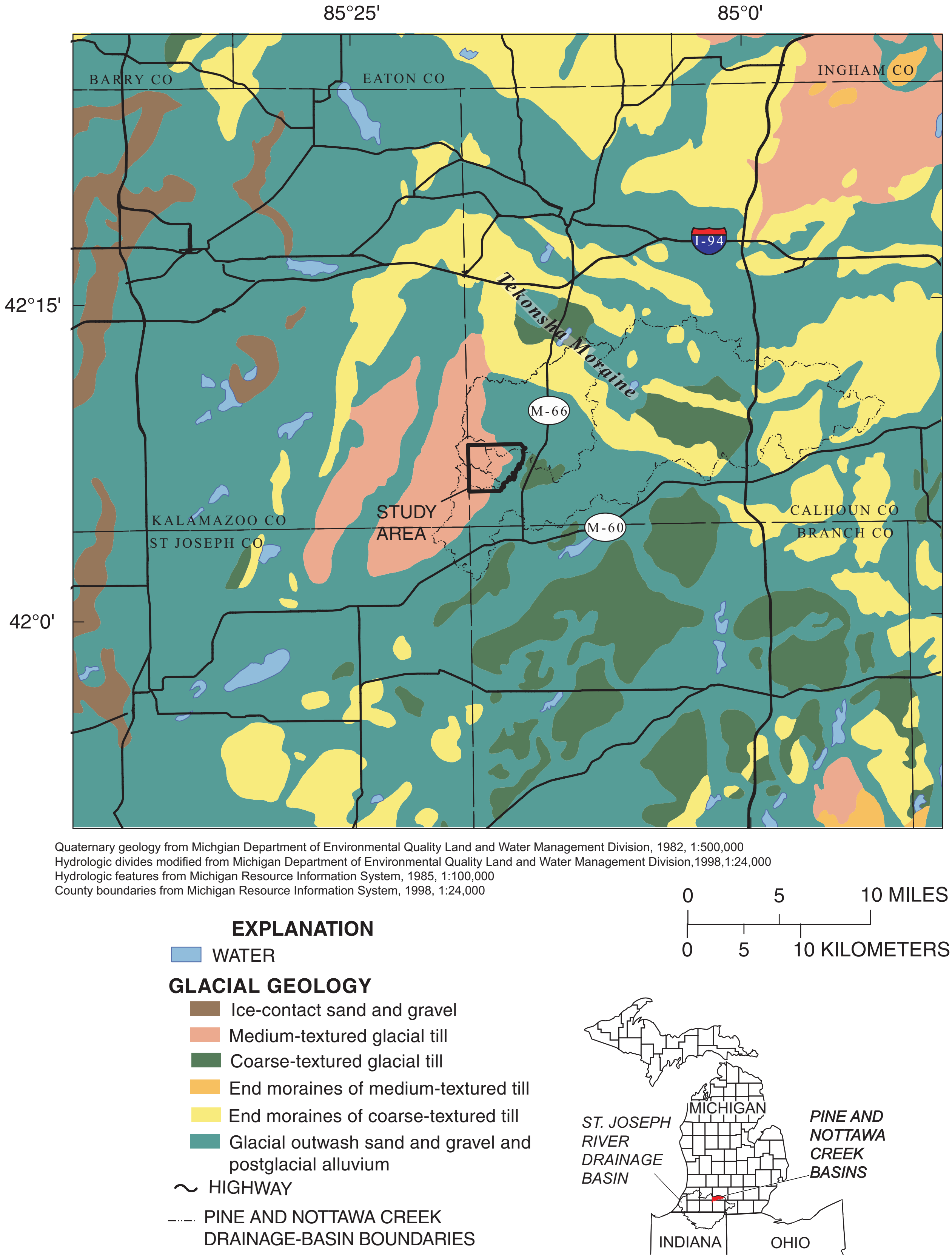


Figure 4. Glacial geology of south-central Michigan.

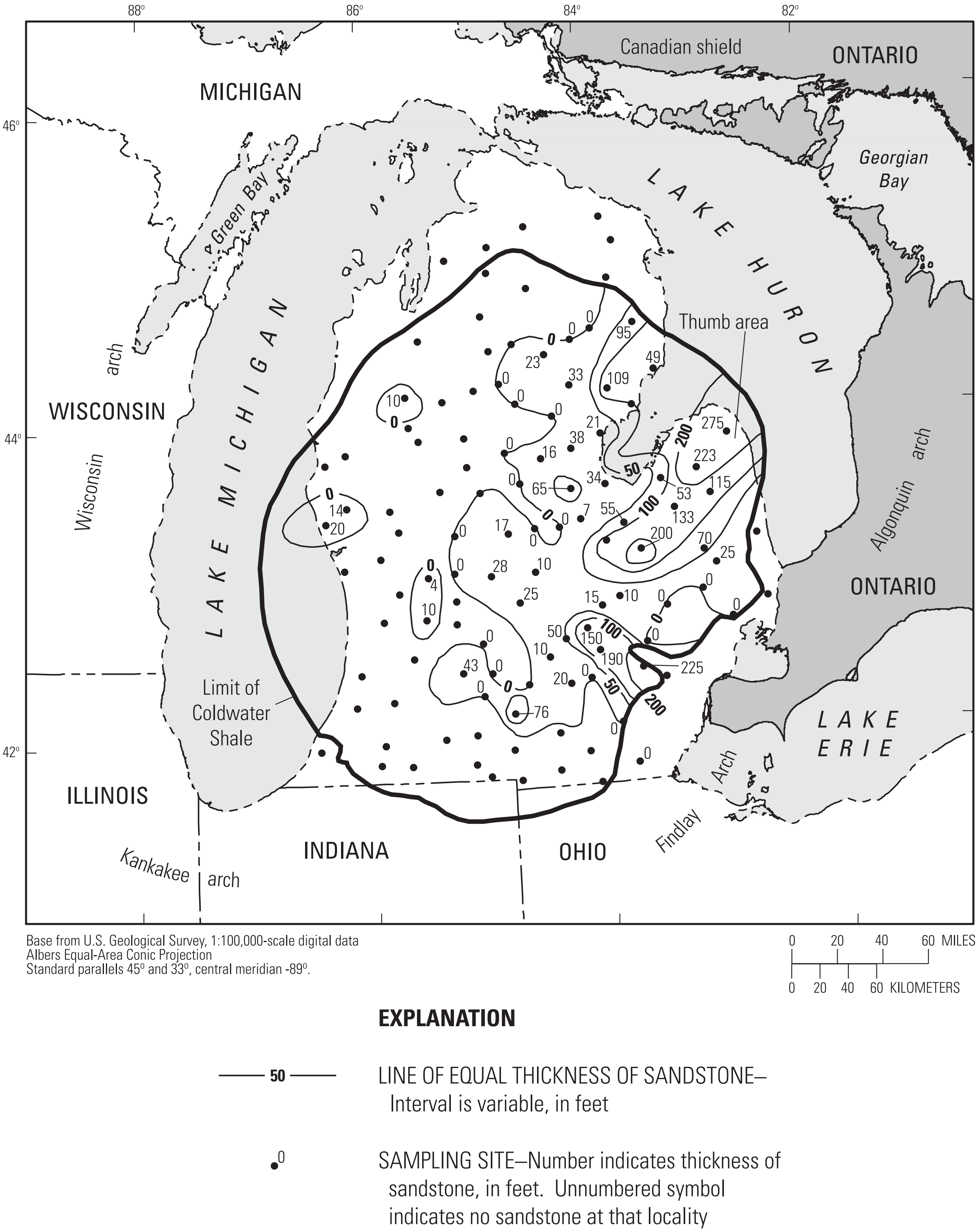


Figure 5. Michigan Basin and cumulative thickness of sandstone in the Coldwater Shale in the Lower Peninsula of Michigan (modified from Cohee, 1979, and Westjohn and Weaver, 1998).

Reservation and most other residents in the study area. Hydraulic conductivity of glacial deposits in the study area is highly variable and directly correlates to the prominent grain size of the aquifer materials (hydraulic conductivity is a measure of the capacity of a geologic formation to allow liquid to flow through it). In areas where deposits are primarily coarse-grained outwash sands and gravels and postglacial alluvium, such as the eastern part of the study area (fig. 4), hydraulic conductivity is high, resulting in excellent infiltration and aquifer recharge. In the western part of the study area, where glacial deposits are primarily medium-textured till (fig. 4), hydraulic conductivity is probably lower, particularly where clay units are present. The presence of clay lenses and layers, even within coarse-grained outwash sands and gravels, can impede or stop the vertical movement of water in an aquifer.

At least three nearby domestic-supply wells are completed in the Coldwater Shale, although details are lacking about whether the wells are obtaining water from the Coldwater Shale or the overlying glacial deposits. Indian Health Service (IHS)completed a test well (TW2) at the Fuller Property in November 2002 that was open to the Coldwater Shale from 83 to 340 ft below the surface (fig. 2). No water-bearing zones were intercepted in the Coldwater Shale, and TW2 was subsequently abandoned. As noted in Westjohn and Weaver (1998), lenses of coarser-grained rock that contain freshwater occur within the Coldwater Shale, but they are known to be discontinuous in the east part of Michigan (fig. 5) and are thin or absent in the study area and to the west (Cohee, 1979).

Ground water from relatively thin (less than 100 ft) but laterally extensive glacial deposits is the sole source of potable water for most households within the study area. Ground water and surface water are both used for irrigation to support agriculture within the basin, although specific locations of agricultural wells and most surface-water pumping sites are not currently known.

Fuller Property

The Fuller Property is on Q Drive South 1.5 mi north and west of the reservation (fig. 2). The tribe purchased the site to develop a housing community for tribal members currently living off the reservation. Before tribal purchase, the property was privately owned agricultural land, and the tribe currently leases the property for agriculture. Three test wells (TW1-TW3) have been drilled on the Fuller Property since tribal purchase (fig. 2). These wells were installed to evaluate water availability and quality before the development of a housing complex on the site; however, water-producing capabilities and water-quality data from TW1 and TW3 should be used with caution because neither well was equipped with a permanent pump or produced for longer than the limited time necessary to complete single-well drawdown test and collect water-quality samples.

Test well 1 (TW1) was drilled in June 2000, intercepting the Coldwater Shale at a depth of 85 ft and completed to a depth of 90 ft. The screened interval of TW1, from 57 to 67 ft consists of brown clay overlying 8 ft of sand. Indian Health Service sampled TW1 for a large suite of water-quality constituents in August 2000 (data available at NHBP). Notably, TW1 tested below the USEPA drinking-water Maximum Contaminant Level (MCL) for nitrate (*www.epa.gov/safewater*). Nitrate is a common pollutant in agricultural areas such as south-central and southwestern Lower Michigan. Common sources of nitrate contamination, in addition to wastewater-treatment plants and other point sources, include runoff or infiltration from fertilized fields, leaching from septic systems, livestock waste, and natural sources. No wastewater-treatment plants or other point sources of sewage entry are known of within the study area or watersheds of Pine Creek, Athens & Indian Creek Drain, or the unnamed tributary to Pine Creek.

Test well 2 (TW2) was drilled close to TW1 in November 2002. Engineers from Indian Health Service installing TW2 hoped the well would intercept useable aquifer units within the Coldwater Shale, and the well was cased through the unconsolidated deposits. Test well 2 intercepted the Coldwater Shale at a depth of 83 ft, was cased to 96 ft, and continued to a total depth of 340 ft. Test well 2 drew down to full depth during a pump test, and was abandoned after no additional aquifer units were intercepted below the bedrock subcrop. As noted previously, few, if any, coarse-grained productive beds within the Coldwater Shale are known near the study area (fig. 5).

Test well 3 (TW3; erroneously called TW2 in laboratory water-quality analysis), was drilled adjacent to the unnamed tributary to Pine Creek in November 2002. Test well 3 was completed in sand and coarse gravel at a total depth of 78 ft, and is screened over the interval from 69.5 to 78 ft. Test well 3 was sampled for a limited suite of water-quality constituents including radionuclides, cyanide, and some pesticides in December 2002 (results available from NHBP). The sample tested below detection level for the analytes and below the USEPA MCL (*www.epa.gov/safewater*) for radionuclides.

Wellhead Protection Area Delineation for the Village of Athens

The Village of Athens completed a wellhead protection area (WHPA) delineation report for their PWS wells in 2000 (Fleis and Vandenbrink Engineering, 2000). The following is a summary of information contained within the WHPA report pertinent to this study.

The near-surface geology of Athens is similar to that found about 2 mi north at the Pine Creek Reservation and the Fuller Property. The surficial deposits consist of one or more glacially deposited sand and gravel aquifers and clay confining units directly overlying the laterally extensive, fine-grained, Coldwater Shale. Younger bedrock units found elsewhere in the Michigan Basin are absent in southwestern Calhoun County. The surface of the Coldwater Shale where it subcrops below glacial sediments is eroded and typically has preglaciation paleoriver courses incised into the surface. Incised river courses typically supply much greater quantities of potable water than the surrounding area, because the sediment within the channels is considerably thicker than it is laterally away from the channels. Such is the case at Athens, where unconsolidated sediments are as thick as 200 ft near Nottawa Creek, which follows an incised channel. Unconsolidated sediments are typically less than 85 ft, and often less than 60 ft in thickness, near the Pine Creek Reservation, although they thicken near Pine Creek.

Both the WHPA report and the previous ground-water investigation at the House of Raeford Farms in Athens noted the presence of an upper and lower aquifer. At the Village of Athens well field, the upper aquifer is unconfined and extends from about 16 to 41 ft below land surface; the lower aquifer is confined and extends from about 96 to 103 ft below land surface. A clay layer about 50 ft thick separates the two aquifers. The Village of Athens is currently operating two PWS wells that are completed in the deeper unconsolidated aquifer, and a shallow PWS well, completed in the upper aquifer, that has been out of service since 1993 because of unacceptable nitrate concentrations. A 24-hour aquifer test of the lower aquifer was completed as part of the WHPA delineation. Transmissivity, which is a measure of the amount of water that can be transmitted horizontally by the full-saturated thickness of the aquifer (Fetter, 1988), ranged from about 4,300 to 5,700 ft^2/d; and storativity, which is the volume of water that a permeable medium will absorb or expel from storage, ranged from about 0.0005 to 0.0006. The lower aquifer was judged to be a leaky-confined aquifer from analysis of the test data, and that interpretation was used for the ground-water-flow model completed as part of the WHPA delineation. The basic relation is

$$K=T/b\ ,$$

where K is hydraulic conductivity, b is aquifer thickness, and T is transmissivity. Hydraulic conductivity of the lower aquifer at Athens ranges from about 4,600 to 6,100 (gal/d)/ft^2, which is typical of an aquifer composed of clean, coarse-sand or fine-gravel (Health, 1983).

The WHPA delineation study found that the water-level surface of the lower aquifer sloped at roughly the gradient of Nottawa Creek and that the ground-water-flow direction was west-southwest. A recharge boundary was reached after about 300 minutes of pumping during the aquifer test. Fleis and Vandenbrink Engineering (2000) extrapolated through a series of standard mathematical calculations that the distance to the recharge boundary was about 2,400 ft and surmised that interception of Nottawa Creek, which is about 2,000 ft north of the Athens PWS wells, was one possible explanation.

Two water-level surface maps were created for the WHPA delineation. The initial map was created with static water levels from drillers' logs, and the second was created with current water-level measurements and the elevation of surface-water features including Nottawa and Pine Creeks. The potentiometric surfaces created from the two different databases are appreciably different, illustrating the problems that can occur when static water levels measured soon after domestic-water-supply wells are completed are used to define a water-level surface representing conditions at a later date.

Drillers' Logs of Wells near the Study Area

A number of drillers' logs of domestic-supply wells near the Pine Creek Reservation are available from Calhoun County Health Department and MDEQ, as are logs for three PWS wells belonging to the Village of Athens and construction diagrams of monitoring wells for the House of Raeford Farms. The Village of Athens WHPA Delineation report (Fleis and Vandenbrink Engineering, 2000) also contains copies of the village and House of Raeford Farms well logs. The appendix to this report contains drillers' logs for two tribal PWS wells and three tribal test wells (TW1-3). Quality of the drillers' logs varies considerably, but generalized information about aquifer materials prevalent in the area is similar for most wells. Most domestic-supply wells are 35 to 65 ft deep and are completed in unconsolidated sediments. Some of the deeper domestic-supply wells reach bedrock at 70 to 90 ft, except near Nottawa Creek in Athens. Clay is noted in logs for most wells, although it appears to be discontinuous and is not noted for all wells. An upper and lower aquifer composed of unconsolidated deposits is present in some locations; and where the lower aquifer is present, it may be partially confined.

DESCRIPTION OF STREAMS AND THEIR WATERSHEDS

The streams draining the NHBP Reservation are part of the St. Joseph River system, which flows in to Lake Michigan. Pine Creek, Athens & Indian Creek

Drain, and the unnamed tributary to Pine Creek are the principal streams within the study area (fig. 2). The unnamed tributary flows eastward across the Fuller Property and into Pine Creek north of the reservation. Athens & Indian Creek Drain flows southward through the west side of the reservation and into Schneider & Schneider Extension Drain south of the reservation; Schneider & Schneider Extension Drain flows into Pine Creek about 0.1 mi south of the reservation. Pine Creek flows into Nottawa Creek about 0.5 mi south of the reservation (fig. 1). The average annual precipitation measured at Battle Creek Airport (about 12 mi north of the study area), is currently about 34 in/yr (Mark Walton, National Oceanic and Atmospheric Administration, written commun., 2001). Average annual runoff for the U.S. Geological Survey gaging station on Nottawa Creek near Athens for the years 1967-97 was 12.77 in., or about 1 ft^3/s per square mile of drainage basin.

This section presents a brief description of physical characteristics of the streams that cross the study area, as well as Nottawa Creek. Physical and geographic characteristics of these streams are listed in table 2.

No lakes are within the reservation, although there are some small ponds (less than 1 acre) nearby. Water quality of the streams will be discussed in a subsequent section of this report. Streamflow (discharge) was measured at the sites according to standard USGS techniques (Carter and Davidian, 1968; Rantz and others, 1982), typically by means of a current meter and wading rod. Results are summarized in table 3. Stage (gage height) was also recorded for each site, measured from reference points surveyed into an arbitrary local datum.

Rantz and others (1982) define a current-meter measurement as the summation of the products of partial areas of the stream cross section (A) times the flow velocity normal to each measuring section (V) as measured with the current meter. Streamflow (Q) is recorded with units of cubic feet or cubic meters per second. The formula is

$$Q = \sum(A \times V) \ .$$

USGS standards currently call for 5 percent or less of the total discharge to be measured in each section, resulting in 20 to 30 sections per measurement, depending on depth of measuring section, width, velocity, and other variables.

Low-flow conditions at Athens & Indian Creek Drain were often difficult to quantify. Two additional methods were used by hydrographers at that site when velocity or depth was too low to accurately measure with a current meter: the Parshall flume and estimation. The Parshall flume is a device that captures and constrains flowing water, allowing for easy measurement. It has an approach reach with converging sidewalls and a level floor, the downstream end of which is a critical-depth cross section. Critical flow is established near that cross section by a sharp downward break in the bed slope of the flume. Primary stage measurement is made in the approach reach, and discharge is computed with a rating table for the flume (Rantz and others, 1982). A Parshall flume works well for low flows but can be difficult to deploy effectively, depending on composition of the streambed. A 3 in. Parshall flume made of stainless steel was used for this study. Streamflow estimation based on an approximated area and an average velocity also works well and requires no tools or setup.

Pine Creek flows from about 7 mi northeast of the traditional reservation (fig. 2), beginning at Cotton Lake (fig. 2). Pine Creek flows about 1/2 mi south of the reservation before emptying into Nottawa Creek about 5.5 mi upstream from a USGS gaging station (station 04096900), which operated continuously from 1967 to 1997. Small tributaries to Pine Creek near the reservation include the unnamed tributary crossing the Fuller Property and Athens & Indian Creek Drain and Schneider & Schneider Drain.

Selection of a suitable site to measure streamflow and collect water-quality samples on Pine Creek near the reservation was hampered by backwater. Pine Creek is

Table 2. Physical and geographic characteristics of streams in and near the study area, Calhoun County, Michigan.

[mi^2, square miles; USGS, U.S. Geological Survey; latitude and longitude given in: °, degrees; ’, minutes; ”, seconds]

Stream name	USGS site identification number	Latitude and longitude of USGS stream-gaging station	Drainage area (mi^2)	Predominant features of unconsolidated deposits in basin
Pine Creek at O Drive South near Athens	04096890	N42° 08’ 02” W85° 13’50”	35.2	Glacial outwash sand and gravel and postglacial alluvium
Unnamed tributary to Pine Creek	04096891	N42° 07’ 32” W85° 16’ 21”	2.3	Medium-textured till
Athens & Indian Creek Drain near Athens	04096894	N42° 06’ 24” W85° 15’ 45”	1.7	Medium-textured till
Nottawa Creek near Athens	04096900	N42° 03’ 20” W85° 18’ 30”	162	Glacial outwash sand and gravel, postglacial alluvium, and coarse-textured glacial till

in backwater where it borders the traditional reservation, and flow is affected for more than a mile north of the reservation as well. A site on O Drive South (N42° 08' 02" W85° 13'50"; site 04096890) (fig. 6) is the furthest downstream site where access was easy, backwater effects were thought to be minimal, and measurement and sampling conditions would be fair to good. Site 04096890 is about 2 mi upstream from the reservation. Considerable aquatic vegetation was typical at site 04096890 during the summer. Stage, which is measured with a staff gage installed in September 2001, was often affected by backwater caused by the vegetation during the period of the measurements. Streamflow measurements were made at site 04096890 beginning in October 2000, and continuing regularly through September 2003. Total drainage area of the Pine Creek Basin upstream from site 04096890 is 35.2 mi^2.

The unnamed tributary to Pine Creek (fig. 2) flows from west to east across the Fuller Property, draining agricultural land to the west. Streamflow measurements were made at a site on the north side of the Fuller Property (N42° 07' 32" W85° 16' 21"; site 04096891) (fig. 7) in April 2001 and 2002 for comparison with Pine Creek and Athens & Indian Creek Drain. No measurements were made in 2003, because of backwater caused by beaver activity and irrigation withdrawals on the Fuller Property. Agricultural chemicals applied on adjacent fields are likely to be present in the stream, as well as petroleum products from diesel-powered irrigation pumps, as was observed in 2003. Tribally owned property surrounding the unnamed tributary to Pine Creek is leased on a seasonal basis to farmers. Crops grown in the immediate drainage basin include alfalfa, corn, and soybeans; the crop most frequently grown adjacent to the sampling site is corn. Total drainage area of the basin upstream from site 04096891 is 2.3 mi^2.

Calhoun County, as well as most other counties in southern Michigan, has a system of dredged drains. The drain that crosses the traditional reservation is known as Athens & Indian Creek Drain; it flows through two sections, west and north of the reservation, before entering section 20 and turning southwest (fig. 2). Athens & Indian Creek Drain flows into Schneider & Schneider Drain immediately south of T Drive South, just beyond the southern end of the reservation. About 0.3 mi east of the confluence, Schneider & Schneider Drain empties into Pine Creek. Athens & Indian Creek Drain is about 3 mi long (Sherry Trader, Calhoun County Drain Commission, written commun., 2003). Streamflow measurements were made at a site adjacent to the traditional reservation (N42° 06' 24" W85° 15' 45"; site 04096894) (fig. 8), beginning in October 2000 and continuing regularly through September 2003 in order to develop a stage-streamflow relation. Stage at the site, which is

Table 3. Streamflow measurements of streams in and near the study area, Calhoun County, Michigan.

[All streamflows are in cubic feet per second; --, indicates no measurement was made; p following the discharge indicates the measurement was rated poor to account for equipment malfunctions; e following the discharge indicates an estimate was made because of low streamflow]

Date of measurement	Pine Creek near Athens 04096890	Unnamed tributary of Pine Creek 04096891	Athens & Indian Creek Drain 04096894	Nottawa Creek near Athens 04096900
05/03/00	32.5	--	--	--
10/04/00	39.9	--	5.61	--
04/12/01	46.6	2.33	2.01	--
05/30/01	70.1	--	2.60	--
04/09/02	87.2	--	4.77p	--
04/23/02	43.5	2.61	1.57	203
08/18/02	14.5	--	.12	63.6
10/01/02	8.38	--	.04e	41.0
11/12/02	--	--	--	53.4
11/13/02	14.7	--	.31e	--
04/29/03	16.2	--	.50	80.2
05/28/03	18.5	--	.63	--
06/09/03	23.9	--	.49	76.2
06/17/03	14.5	--	--	--
07/17/03	7.24	--	--	--
07/30/03	5.38	--	.05	33.7
08/20/03	7.25	--	--	--
09/10/03	6.59	--	--	--

measured with a staff gage installed in September 2001, is occasionally affected by debris. Agricultural chemicals applied on adjacent fields are present in the stream, and the highest concentration of atrazine noted at all sampled sites during this study was collected at this site. Total drainage area of the Athens & Indian Creek Drain basin upstream from site 04096894 is 1.7 mi^2.

USGS operated a continuous-record streamflow-gaging station (N42° 03' 20" W85° 18' 30"; station 04096900) on Nottawa Creek near Athens (fig. 1) from 1967 to 1997. In 2003, as part of the current study, streamflow measurements were made at Nottawa Creek the same day as those made at Pine Creek and Athens & Indian Creek Drain. Despite some differences in hydrological setting, the basins are similar enough to allow some basic basin comparisons to be made. Considerable aquatic vegetation was typically present at station 04096900 during the summer, and when it was operated as a continuous-record site with a stage-discharge rating, considerable effort was expended to ensure the streamflow computed from the stage was correct. Variable-stage-shifting techniques were used where streamflow measurements and recorded stage were compared with the stage-discharge rating. Typically, as aquatic vegetation grows, stage rises even though streamflow may actually be stable or decreasing; this pattern continues until vegetation growth plateaus or, as is most common in Michigan streams, winter die-off begins. During the winter, most streams return to rating conditions unless freezeup causes ice backwater conditions.

For the current study, only streamflow was considered; no physical properties were measured or water-quality samples collected. The drainage area contributing to the site is calculated to be 162 mi^2 (Blumer and others, 1998) and incorporates the drainage areas of Pine Creek, Athens & Indian Creek Drain, the unnamed tributary to Pine Creek, and all other upstream tributaries of Nottawa Creek.

Rheaume (1990) used hydrograph-separation techniques for streamflow data collected at Nottawa Creek during low-, medium, and high-precipitation years (1971, 1977, and 1985, respectively). The hydrograph separations showed that water loss averaged 27.86 in/yr, surface-water runoff averaged 3.69 in/yr, and ground-water runoff averaged 6.89 in/yr. The study compared streams with various types of basin characteristics and interpreted the Nottawa Creek Basin as comprising primarily glacial till. Water loss was about 4 in/yr less and ground-water runoff was about 4 in/yr more in the

Figure 6. 04096890, Pine Creek at O Drive South near Athens, Michigan, looking northeast.

Augusta Creek Basin, where coarser glacial deposits and greater infiltration are more typical.

STREAMFLOW ANALYSIS

Data from the former USGS gaging station at Nottawa Creek near Athens (station 04096900), which operated continuously from 1967 to 1997, were used for making basin comparisons with Pine Creek and Athens & Indian Creek Drain. Four other nearby USGS gaging stations that have operated continuously since 1967 were also incorporated into the analyses to verify the continuity of trends between 1967 and 1997 and the period of this study. These stations are St. Joseph River at Burlington (station 04096405), Prairie River near Nottawa (station 04097540), Battle Creek at Battle Creek (station 04105000), and Augusta Creek near Augusta (station 04105700). These four stations are located within 20 mi of the study area, and at least part of their respective drainage basins is similar to those of this study. Comparisons of Nottawa Creek near Athens with the four other stations indicated that Prairie River near Nottawa was most similar to Nottawa Creek near Athens between 1967 and 1997, and this station was chosen as the comparison station for 2001-03. The following discussion details steps completed to show that basin characteristics of one or more of the continuously operating gaging stations were applicable for estimating daily discharge at Pine Creek and Athens & Indian Creek Drain.

The first step was to create stream-duration curves (duration of flow is the distribution of streamflow with time). The percentage of time that a specific streamflow from the five streams discussed previously was equaled or exceeded is shown in figure 9. For example, the streamflow of Nottawa Creek near Athens equaled or exceeded 0.76 $ft^3/s/mi^2$ about 50 percent of the time. Multiplying the unit discharge value (0.76) by the area of the drainage basin (162 mi^2) shows that Nottawa Creek discharged 123 ft^3/s or more 50 percent of the time.

Streamflow-duration curves are useful for relating streamflow to the physical characteristics of a basin. The upper end of the curve reflects the direct runoff characteristics, which are affected by climate, topography, and land use. The lower end of the curve reflects base-flow characteristics, which usually depend on the capacity of material underlying the basin to store and transmit water. A relatively steep slope on the lower end

Figure 7. Site 04096891, unnamed tributary to Pine Creek, near Athens, Michigan, looking southwest.

of a curve compared to the rest of the curve indicates that the volume of ground water available to sustain streamflow during dry weather is minimal. A relatively flat slope on the lower end of the curve indicates that streamflow is being sustained during dry weather by ground-water discharge, the addition of municipal or industrial wastes, or upstream reservoir regulation.

The streamflow duration curve for Battle Creek is typical of basins that are heavily urbanized; specifically, the slope in the part of the curve under 10-percent exceedance is a relatively steep when compared to that for the other streams. However, the Battle Creek Basin is not heavily urbanized upstream from the streamflow-gaging site, and the steep slope in the upper flow regimes is probably the result of the dam, or tighter (less permeable) soils, or some other environmental factor not affecting the other comparison streams. All five streams in this analysis are unregulated and flowed continuously during the period analyzed. Of the four comparison streams, Prairie River compared most closely with Nottawa Creek, and their respective flow-duration curves are nearly identical (fig. 9). Augusta Creek showed an appreciable contribution from ground-water discharge throughout most of the curve, as indicated by a fairly flat slope. The St. Joseph River at Burlington showed the least amount of contribution from ground-water discharge as indicated by the relatively steeper slope compared with the curve for Augusta Creek.

Distribution of streamflow can also be described as the amount of annual streamflow that occurs each month (fig. 10). The distribution curves for Prairie River and Nottawa Creek closely parallel or nearly overlie each other during most months. All five stations showed the greatest streamflow during March and April and the least in August and September. Battle Creek showed the most variation, from 16 percent in March to 3.7 percent in August, probably because of the previously-referenced effects on runoff during the wettest months. Augusta Creek showed the least amount of variation, from 11 percent in April to 6.4 percent in August, probably because of ground-water contribution to total discharge of that stream.

Distribution patterns among the five streams are similar when data are plotted as streamflow per square mile (fig. 11). Streamflow-duration and streamflow-distribution curves indicate that Nottawa Creek and Prairie River correlate well with each other and should be equally useful for comparison purposes with the

Figure 8. Site 04096894, Athens & Indian Creek Drain near Athens, Michigan.

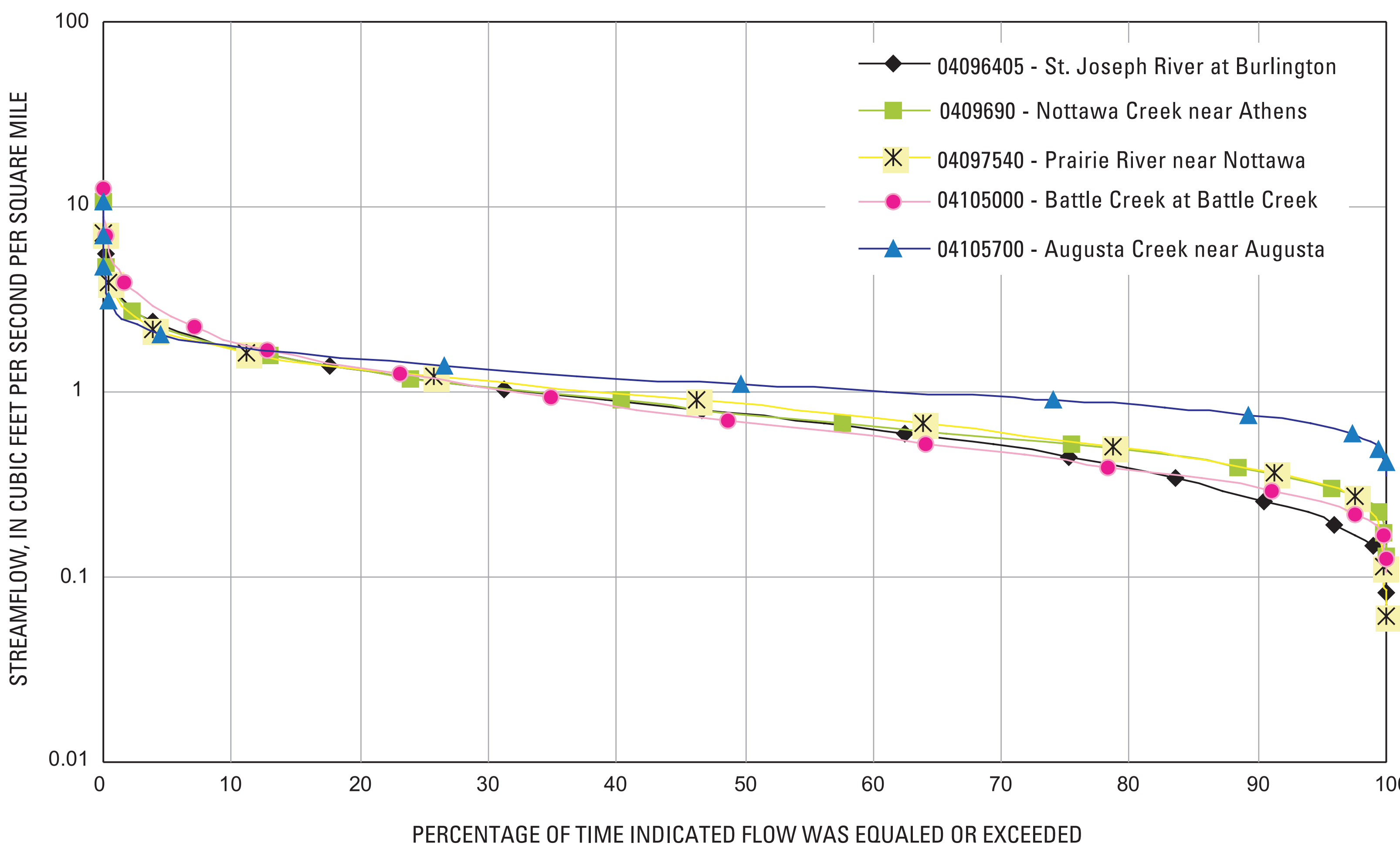


Figure 9. Streamflow-duration curves for U.S. Geological Survey streamflow-gaging stations near the study area, Lower Peninsula of Michigan (1967-97).

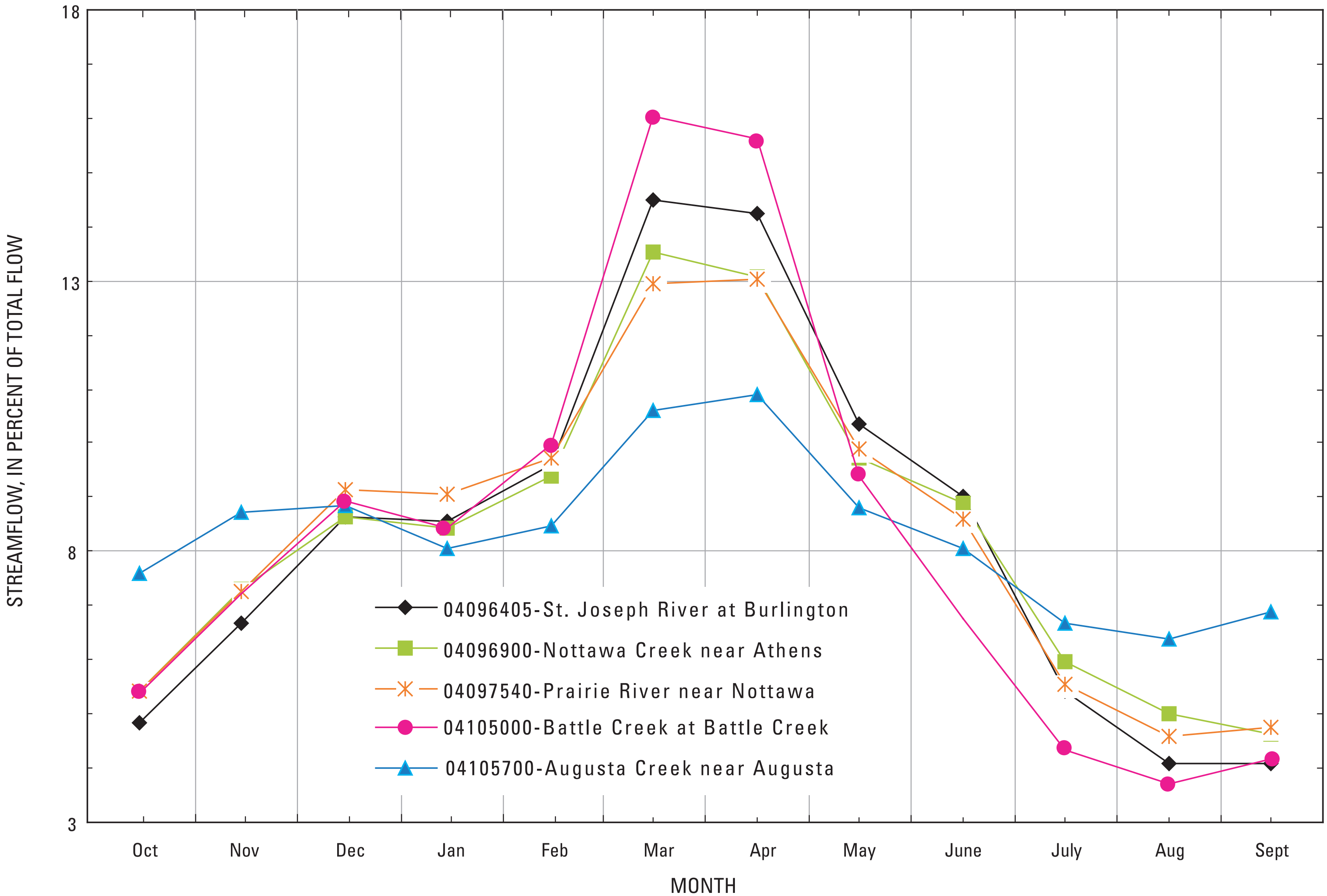


Figure 10. Streamflow-distribution curves for U.S. Geological Survey streamflow-gaging stations near the study area, Lower Peninsula of Michigan (1967-97), in percent of total flow.

streams in the study area. As might be anticipated, the distribution curves for Prairie River and Nottawa Creek were closely parallel or nearly overlie one another in this permutation as well.

A stage-streamflow rating for Pine Creek is shown in figure 12. The rating was constructed with streamflow measurements made at Pine Creek and plotted with the most recent rating-curve information for Nottawa Creek near Athens, multiplied by the drainage-area ratio of Pine Creek to Nottawa Creek (35.2/162). The dark blue line is rating 7 for Nottawa Creek, and the blue squares represent measurements made during this study. No stage-shift curves are shown for Nottawa Creek on figure 12, although measurements 321 and 326 plot well to the left of rating 7, indicating that a substantial negative stage shift (probably because of backwater caused by vegetation) is defined by those measurements. The green line is the stage-discharge rating for Pine Creek, and the green circles represent measurements made during this study. The dashed lines are typical stage-shift curves for Pine Creek. The dashed blue stage-shift curve left of the Pine Creek rating curve would be typical for a site where stage is affected by aquatic vegetation growth in the channel. Aquatic vegetation growth can cause backwater, which results in a lower streamflow for any given stage compared to times when the channel is clear. Most growing season streamflow measurements made at Nottawa Creek in 2003 and previous years (1967-97) were affected by backwater, typically caused by heavy aquatic vegetation growth in the channel, as were streamflow measurements made at Pine Creek. The dashed red shift curve to the right of the Pine Creek rating would account for scour or some other alteration of the control, resulting in an increase in streamflow for any given stage. Scour of a control is typically caused by high flows resulting from storm runoff, but it can result from seemingly benign activities such as children moving rocks in a riffle or channel. Each stage-streamflow rating can be refined with additional measurements. The current rating could be better defined if continuous-stage data were available and if additional streamflow measurements were made at the site; however, the current rating is sufficient for the purposes of this study.

Athens & Indian Creek Drain streamflow correlated poorly with the five streams chosen for comparison (fig. 13). The correlation was particularly poor during October 2000 through May 2002; when streamflow per square mile for Athens & Indian Creek Drain was 2 to 3 times greater than the comparison streams. The correlation improved through the remainder of the study. No reason for the initial poor correlation or later better correlation is known, although artificial drainage, such as tiled fields, could be one source. Because of the poor initial correlation with streams that correlated well with Pine Creek, a different method of producing a stage-discharge rating curve was used. Polynomial regression with 7 of the 12 measurements was chosen to construct a hypothetical rating curve (fig. 14). The excellent fit of the results is probably an artifact of the limited range in stage and streamflow of available measurements and may not be indicative of the usefulness of the rating curve. It is possible that the stage-discharge rating approximation is usable over the range of stage illustrated; but without measurements at higher stages and streamflow, the use of this approximation in defining streamflow for a specific stage should be limited to qualitative approximations only.

Continuous-stage data were not collected at Pine Creek for this study. Streamflow measurements at Pine Creek were also sporadic and represent only an instantaneous streamflow without taking into account other variables that are considered when a site is equipped as a continuous-record station. Daily mean streamflow can be estimated for Pine Creek for the period of the study by use of the previously completed basin-analysis information. Streamflow derived in this manner is an estimate and should only be used as such. Nonetheless, it provides some information for a stream where none was previously known and no continuous-record information is available.

A hydrograph constructed with daily streamflow data from the currently operating USGS gaging station at Prairie Creek near Nottawa (station 04097540) multiplied by the ratio of the basin drainage areas of Pine and Prairie Creeks (35.2 mi^2/106 mi^2) is shown in figure 15. Measured streamflow for Pine Creek is also plotted, partially verifying the hypothetical hydrograph. Actual and hypothetical streamflow may vary because data for Prairie Creek were routinely adjusted by applying and removing of variable stage shifts to account for changes in the control. No similar adjustments of the stage-streamflow relation were made at Pine Creek.

An estimate of daily mean streamflow for Athens & Indian Creek Drain was not considered in this study because of the previously mentioned initial poor correlation with the comparison streams. Further comparison studies with data from other streamflow-gaging stations and additional streamflow measurements made at Athens & Indian Creek Drain, over a broader range of stage and streamflow conditions, are warranted prior to estimating daily mean streamflow for this stream.

WATER QUALITY

Water-quality samples were collected at six domestic-supply wells and one PWS well on or near the NHBP Reservation and three surface-water sites on Pine Creek, Athens & Indian Creek Drain, and the unnamed tributary to Pine Creek. All sampling was done by use of standard techniques described in the USGS “National Field

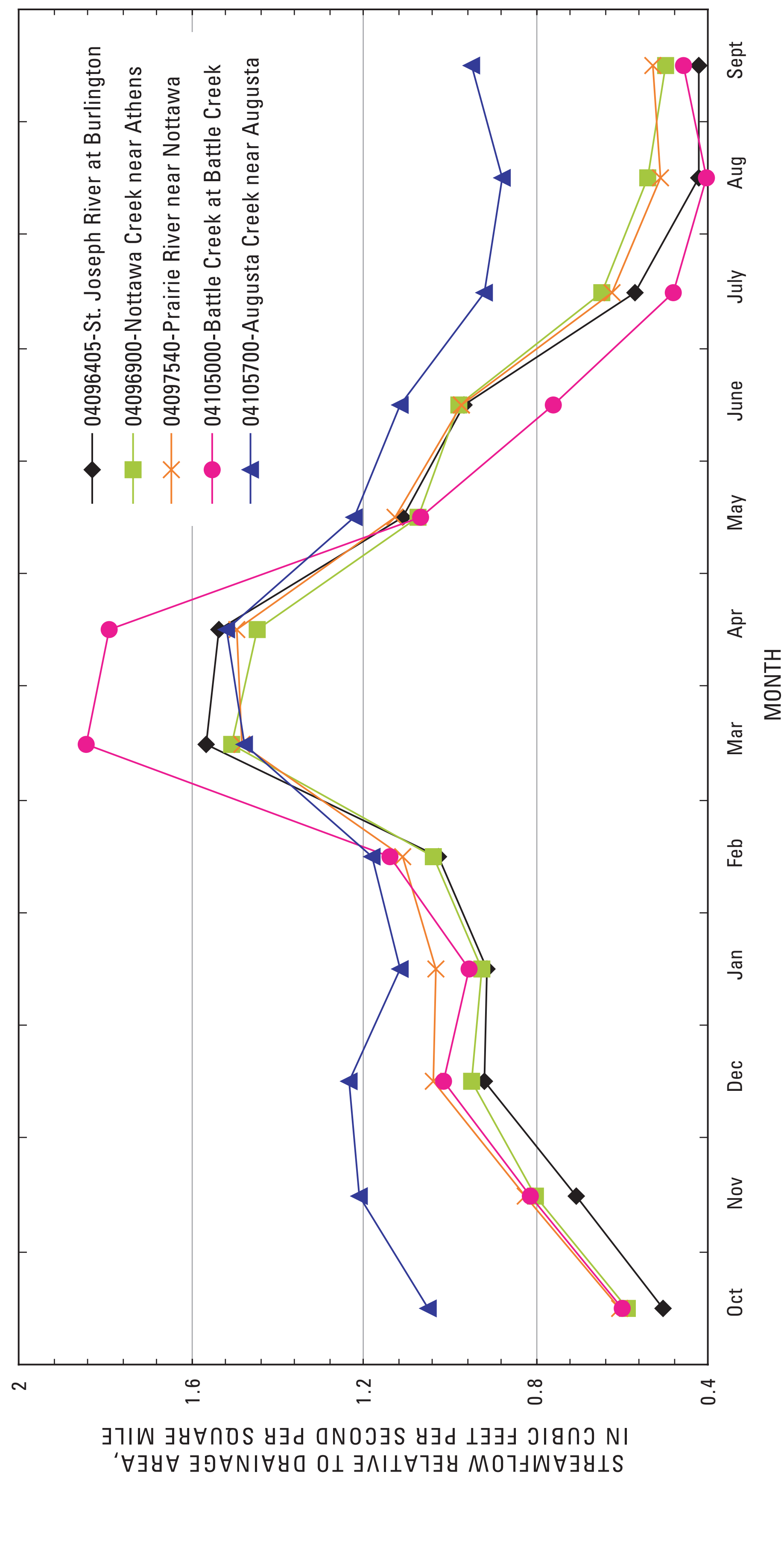
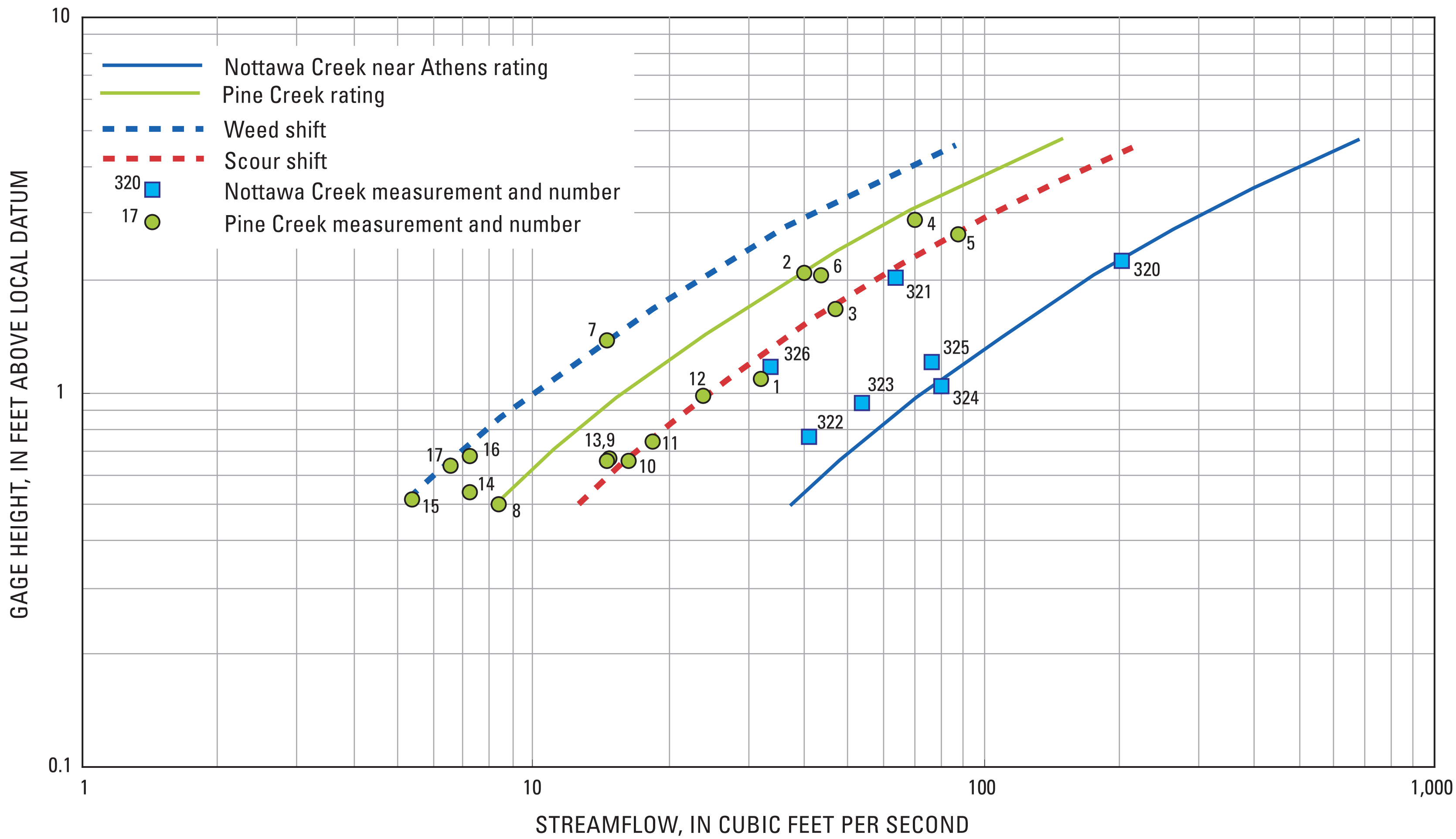


Figure 11. Streamflow-distribution curves for USGS U.S. Geological Survey streamflow-gaging stations near the study area, Lower Peninsula of Michigan (1967-97), in streamflow per square mile of drainage area.



Fiugre 12. Stage-streamflow rating curve for Pine Creek at O Drive South near Athens, Michigan (04096890) derived from rating curve 7 for Nottawa Creek near Athens, Michigan (04096900).

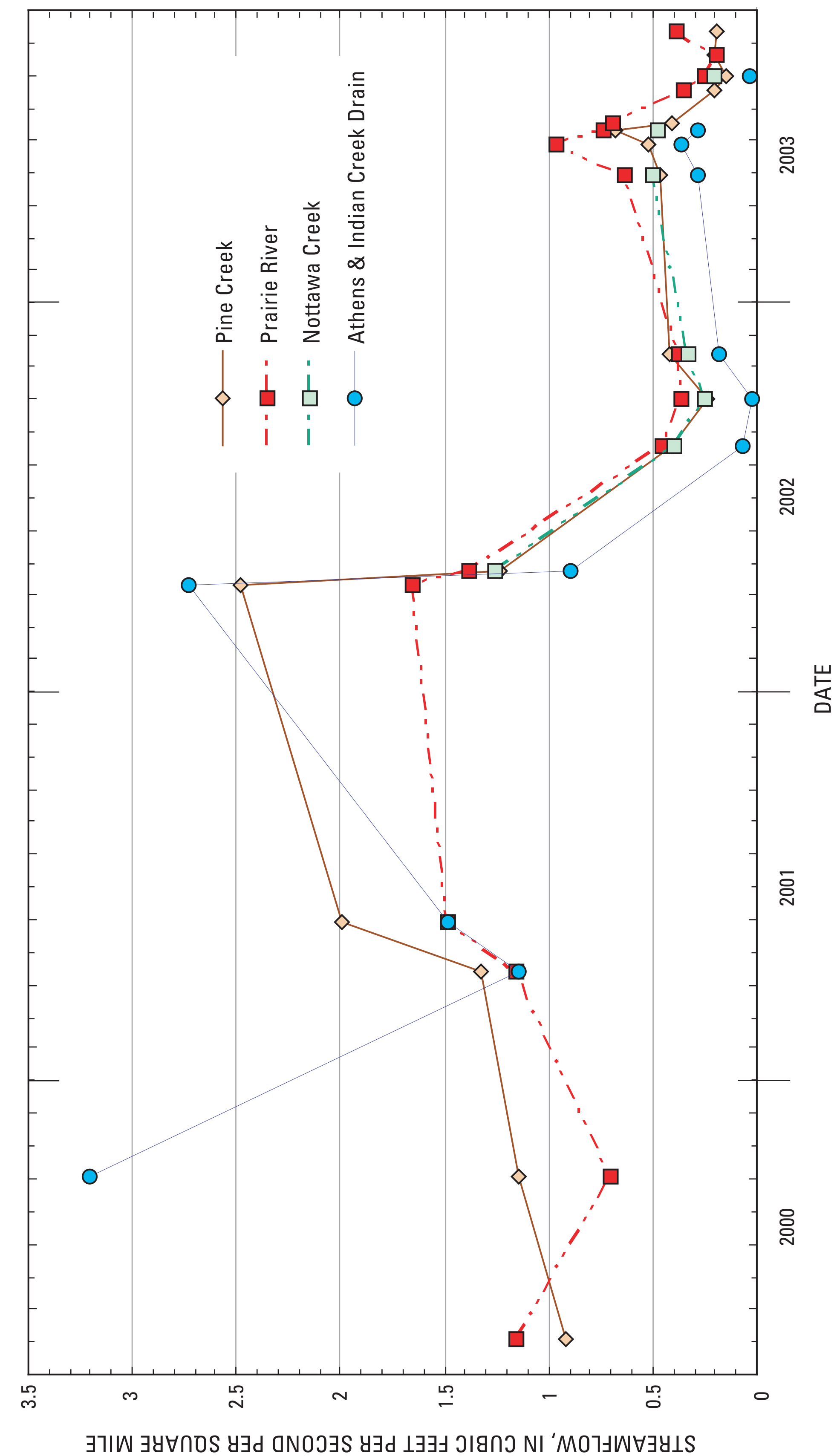


Figure 13. Streamflow, per square mile of drainage area, for streams in the study area and comparison streams, Lower Peninsula of Michigan.

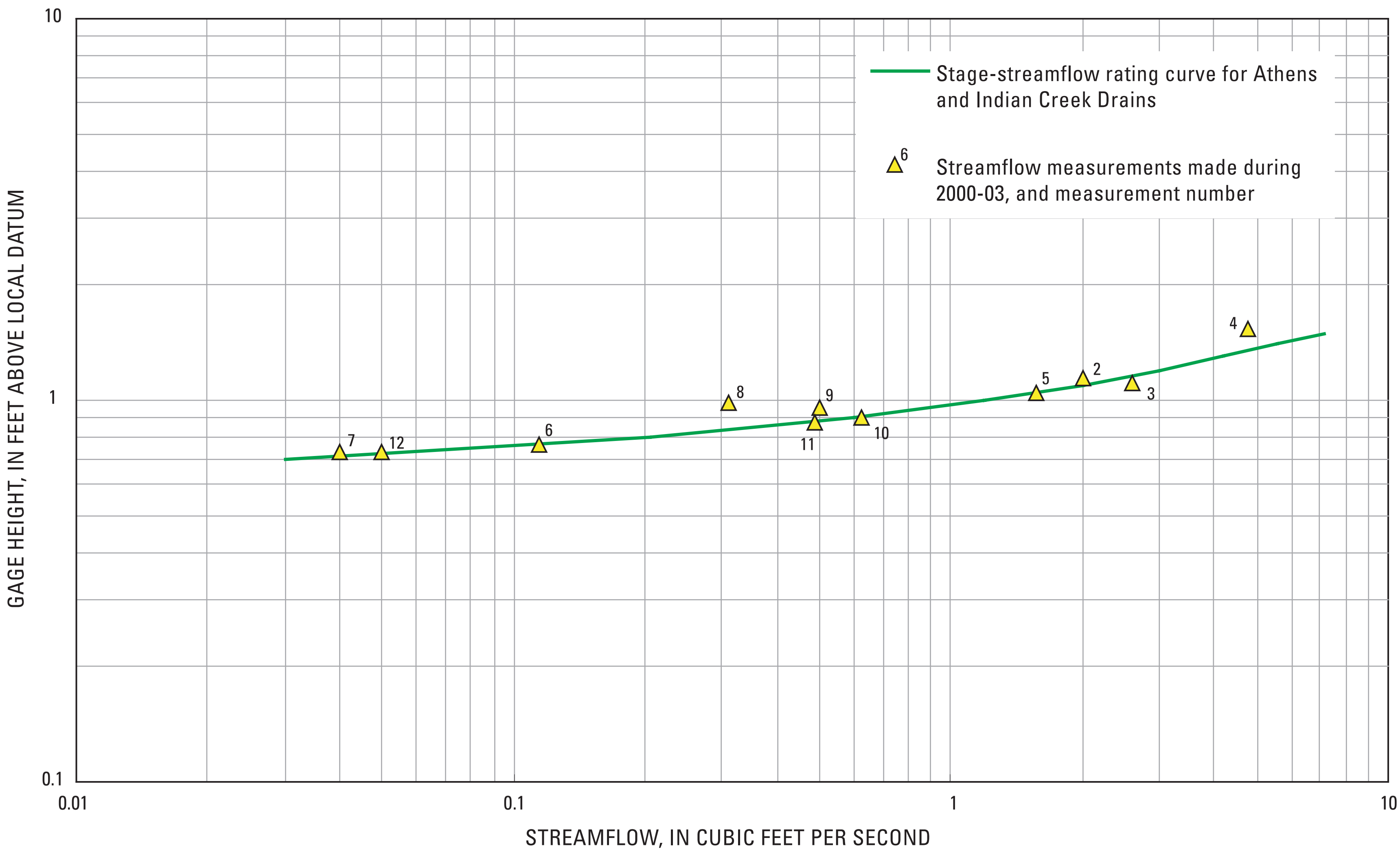


Figure 14. Stage-streamflow rating curve for Athens & Indian Creek Drain near Athens, Michigan (04096894).

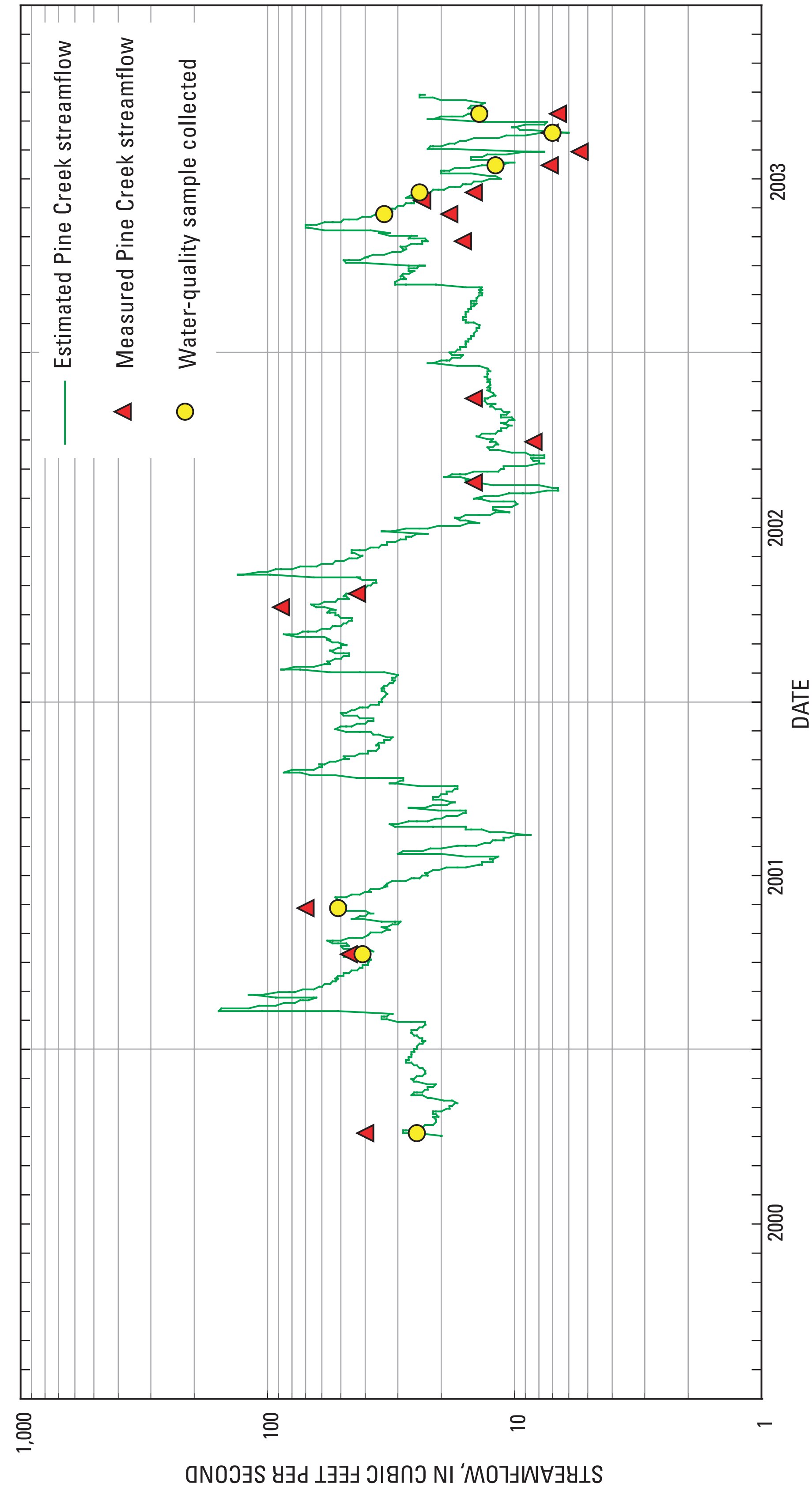


Figure 15. Estimated streamflow of Pine Creek at O Drive South near Athens, Michigan (04096890) for the period from June 2000 through September 2003.

Manual for the Collection of Water-Quality Data" (Wilde and others, 1998) and in accordance with the QAPP. All samples, except the mercury samples, were analyzed at the USGS National Water-Quality Laboratory (NWQL) in accordance with the QAPP. Mercury samples were analyzed at the USGS Wisconsin District Mercury Laboratory. Water-quality samples were analyzed by NWQL using a variety of schedules and procedures. Lists of parameter names, parameter codes, Chemical Abstracts Service (CAS) numbers, method reporting levels (MRL), and references specific to the schedules and procedures are available from NWQL. Quality-assurance/quality-control samples were collected and analyzed in accordance with the USGS guidelines and the QAPP.

In the following sections, tabulated data are reported as uncensored, censored, or estimated. Uncensored data are data reported as an unqualified numerical value. Censored data are reported as being less than a particular reporting level; for example, less than 0.12. Censored data result from the analyte not being present or, if seemingly present, an inability to conclusively identify it. Estimated data are reported as qualified numerical values with an "E" before the number; for example, E.057. Estimated values can be less than, at, or greater than the analytical reporting level. An estimated value less than the reporting level means that the analyte can be identified and measured but with less than 99-percent confidence that it is present. Estimated values at or above the analytical reporting level can result from a poor performance record of the analyte with the analytical method, matrix interference, or small sample volume.

Reporting levels used by the USGS NWQL are minimum reporting level (MRL), method detection limit (MDL), long-term method detection limit (LT-MDL), and laboratory reporting level (LRL). The MRL is the lowest measured concentration of an analyte that can be reliably reported. The MDL is the minimum concentration that can be measured and reported with a 99-percent confidence that the analyte is present. The LT-MDL is derived from the standard deviation of a minimum of 24 MDL spike samples over an extended period. The LRL is generally equal to twice the LT-MDL. The probability of reporting an analyte as a nondetection, when it is present, is less than 1 percent at the LRL. The LRL is used when NWQL determines that an MRL is no longer appropriate to a specific analyte or analytical method (Oblinger Childress and others, 1999). Concentrations measured between the LRL and LT-MDL are reported as estimated concentrations.

Ground-water samples, which were collected only in 2003, were analyzed for a suite of commonly applied agricultural pesticides and their degradates, plus caffeine, using NWQL schedules 2001, 2002, and 2050/2060. In Calhoun County in 2001, atrazine was the most commonly applied pesticide (Donald Sutherland, U.S. Environmental Protection Agency Region 5, written commun., 2001). Alachlor, atrazine, bentazon, and metolachlor have been distributed and applied in Calhoun County and were found in ground water during a study by the Michigan Department of Agriculture in 2000-01.

Surface-water samples, which were collected from October 2000 through September 2003, were analyzed for major ions, solids, nutrients, carbon concentration and absorbance, common trace elements, commonly applied agricultural pesticides and their degradates, caffeine, and mercury. Caffeine was included as an analyte because it is also considered an indicator of human influence on a water body or aquifer, as are pesticides. Unlike pesticides, which are typically applied across a relatively large area and can infiltrate an aquifer in many places, caffeine is typically an indicator of a point-entry source into the aquifer, such as leakage from a household septic system or wastewater-treatment plant. NWQL schedules and procedures used were 1010, 2001, 2002, 2050/2060, 2701, and 2703, as well as the USGS Wisconsin District Mercury Laboratory protocol (DeWild and others, 2002; U.S. Environmental Protection Agency, 2003).

Ground-Water Quality

Between January and September 2003, the USGS collected 11 ground-water samples from 7 wells on or adjacent to the traditional reservation. Six of the wells were domestic-supply wells owned by tribal members living on or near the reservation, and the seventh was the PWS well at the tribal office building. Three of the wells were sampled two or more times to document any chemical changes that might have resulted from aquifer recharge, which most typically occurs in late winter to spring in aquifers in the southern Lower Peninsula.

Ground-water samples were analyzed for 184 pesticides and degradates, plus caffeine. There were five detections of four pesticides or degradates in the nearly 1,300 analyses (table 4). All five detections are reported as estimated values because the compounds were below reproducibility and variability standards for the laboratory analytical methods (Furlong and others, 2001; Zaugg and others, 1995). None of the four pesticides and degradates listed in table 2 are included among the USEPA MCL's (*www.epa.gov/safewater*). The remaining 181 analytes were all below laboratory reporting levels.

Deethylatrazine (CIAT) and 2-hydroxy-atrazine (OIET) are degradation products of the pesticide atrazine. Atrazine, a triazine herbicide, is used to control weeds in corn, sorghum, and other crops common in southern Lower Michigan and is one of the most commonly detected pesticides in surface water and ground water in the United States. The USEPA MCL for

drinking water for atrazine is 3 µg/L. Imazethapyr is an imidazole compound that is a general-use pesticide used to control grasses and broadleaf plants. USEPA has not established a drinking-water standard for Imazethapyr, which they classified as slightly toxic; however, the State of New York issued a ban in 2000 on the use of Imazethapyr on Long Island because of its mobility and persistence in ground water (*www.dec.state.ny.us/website/dshm/pesticid/pesticid.htm*). Azinphos-methyl (Guthion) is a highly toxic organophosphate insecticide used to protect a variety of crops from leaf-eating insects and is not normally found in ground water (Holmes and others, 1999). The estimated value of Guthion in HP2 of 0.305 µg/L may be the result of contamination from leaves that were found in the spigot and water feed pipes after the initial sample was obtained. USEPA has also not established an MCL for azinphos-methyl.

Surface-Water Quality

USGS collected 12 samples at Pine Creek, Athens & Indian Creek Drain, and the unnamed tributary to Pine Creek, during October 2000 through September 2003. Eight samples were analyzed for major elements, solids, nutrients, carbon, absorbance, and trace elements at the three surface-water sites. In 2003, four additional samples were analyzed for pesticide schedules only. Sampling dates are shown on the estimated hydrograph of streamflow for Pine Creek at O Drive South (fig. 15), illustrating the flow rate present when each of the samples was collected. Sampling was scheduled to coincide with expected and observed application of pesticides throughout agricultural lands in southern Calhoun County, as well as periods when pesticide applications were not expected. Documenting the range of pesticide application periods to establish a baseline necessitated that sampling span spring, summer, and fall. Additional sampling during winter could be used to further define baseline conditions but was not done during this phase of the study.

The sampling routines were altered as the study progressed and data were reviewed. Initially, sampling included NWQL schedules 1010 (carbon and nutrients), 2001 and 2050 (pesticides), 2701 (major inorganics), and 2703 (trace elements). In 2003, the pesticide sampling routine was altered without effect when NWQL replaced schedule 2050 by 2060 (because of changes in analytical procedures) and with the addition of schedule 2002 for moderate-use pesticide degradates.

Analytical data are summarized in the following tables: table 5, physical properties, major ions, solids, nutrients, and carbon concentrations and absorbance; table 6, trace elements; and table 7, pesticide/herbicides and caffeine detections in surface water-samples. Four samples collected at Pine Creek during 2003 consisted of three pesticide schedules (2001, 2002, 2060), and these results are included in table 7. Additionally, Pine Creek and Athens & Indian Creek Drain were each sampled once in July 2003 for mercury (total, methyl, and particulate) and results of those analyses are listed in table 8.

Results of the surface-water sampling indicate that the water can be classified as very hard (Hem, 1985),

Table 4. Pesticide detections in ground water sampled from Nottawaseppi Huron Band of Potawatomi Indian Tribe wells, Calhoun County, Michigan.

[All concentrations are µg/L (micrograms per liter); <, less-than symbol used when no analyte was detected; -, pesticide not analyzed for; E, estimated value; shaded values are samples with detected concentrations; LRL, laboratory reporting level, MRL, minimum reporting level]

		Deethylatrazine [CIAT]	2-Hydroxy-atrazine (OIET)	Imazethapyr	Azinphos-methyl
		Report limit and type			
Well name	Date	0.006L LRL	0.008 MRL	0.017 MRL	0.050 LRL
HP 1	Jan. 16, 2003	<0.006	-	-	<0.050
HP 1	May 29, 2003	<.006	E.011	<0.017	<.050
HP 1	June 11, 2003	<.006	E.007	<.017	<.050
HP 2	Jan. 16, 2003	<.006	-	-	E.305
HP 2	Jun. 17, 2003	<.006	<.008	<.017	<.050
HP 3	Apr. 03, 2003	<.006	-	-	<.050
HP 3	May 29, 2003	E.005	<.008	<.017	<.050
HP 4	Apr. 03, 2003	<.006	-	-	<.050
HP 5	Apr. 03, 2003	<.006	-	-	<.050
HP 6	May 29, 2003	<.006	<.008	E.009	<.050
HP 7	June 11, 2003	<.006	<.008	<.017	<.050

Table 5. Streamflow, physical properties, major elements, solids, hardness, nutrients, and carbon concentrations and absorbance in streams in the study area, Calhoun County, Michigan.

[ft^3/s, cubic feet per second, µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; --, no data; fil, filtered; unfil, unfiltered; <, less than; E, estimated value; **, a general State surface-water criterion has been established for this analyte; N, nitrogen; sus, suspended sediment; P, phosphorus; UV, ultraviolet; nm, nanometers]

		Pine Creek at O Drive South 04096890				Unnamed Tributary to Pine Creek 04096891	Athens & Indian Creek Drain 04096894		
Property or Constituent	**Units**	**10/4/00**	**4/12/01**	**5/30/01**	**5/28/03**	**4/12/01**	**10/4/00**	**5/30/01**	**5/28/03**
Streamflow, physical properties, major elements, solids, and hardness									
Streamflow	ft^3/sec	39.9	46.6	70.1	18.5	2.33	5.61	2.60	0.63
Specific conductance	µs/cm	372	428	376	488	385	378	434	543
Water temperature	°C	14.0	14.0	15.5	19.0	14.5	12.8	13.9	14.7
pH	pH units	7.3	7.6	--	--	7.6	7.2	7.1	--
Dissolved oxygen	mg/L	7.5	7.7	--	8.0	8.7	6.0	7.4	7.9
Calcium	mg/L	50.6	63.8	55.7	64.8	55.4	51.0	62.6	75.8
Magnesium	mg/L	13.0	15.3	13.4	16.4	14.3	13.2	16.0	19.5
Potassium	mg/L	2.5	1.3	.6	1.0	1.2	2.7	1.2	.9
Sodium	mg/L	3.2	5.7	4.6	6.6	3.1	5.1	4.8	5.0
Alkalinity	mg/L as $CaCO_3$	127	--	175	--	174	155	171	--
Acid neutralizing capacity	mg/L as $CaCO_3$	--	169	--	--	--	--	--	--
Bicarbonate, fil	mg/L	155	--	213	--	212	189	208	--
Bicarbonate, unfil	mg/L	--	206	--	--	--	--	--	--
Chloride	mg/L	10.7	13.1	8.9	14.4	8.3	11.4	13.9	14.6
Fluoride	mg/L	<.1	<.16	E.10	<.17	E.09	<.1	E.12	<.17
Silica	mg/L	7.5	5.4	8.7	7.6	6.7	8.9	9.6	7.0
Sulfate	mg/L	26.4	24.3	14.7	24.0	19.9	16.2	25.2	52.4
** Residue on evaporation, 180°C	mg/L	240	277	270	296	254	227	288	330
Hardness	mg/L as $CaCO_3$	180	220	190	230	200	180	220	270
Nutrients									
Ammonia, fil	mg/L as N	<0.020	<0.041	<0.040	0.062	<0.041	<0.020	0.044	0.048
Ammonia + organic nitrogen, fil	mg/L as N	.95	.64	.92	.50	.71	.48	.90	.72
Ammonia + organic nitrogen, unfil	mg/L as N	1.2	.77	1.0	1.1	.83	.96	.96	.81
Nitrate + Nitrite, fil	mg/L as N	4.4	.93	.30	.87	.31	.46	5.6	2.4
Nitrite, fil	mg/L as N	.013	.011	.006	.016	.010	<.01	.018	.036
Particulate nitrogen, sus	mg/L	.17	.050	.075	.46	.127	.085	.088	.041
Phosphorus, fil	mg/L as P	.060	.015	.020	.015	.022	.035	.024	.021
Orthophosphate	mg/L as P	.046	E.005	.007	.009	.010	.024	.013	.012
Phosphorus, unfil	mg/L as P	.032	.033	.062	.093	.041	.040	.046	.034
Carbon and absorbance									
Carbon, inorganic + organic, sus	mg/L	2.1	0.47	0.38	5.7	1.3	1.3	0.85	0.59
Carbon, inorganic, sus	mg/L	<.12	<.12	<.12	.13	<.12	<.12	<.12	<.12
Carbon, organic, fil	mg/L	14.4	11.0	15.5	7.28	12.5	9.55	11.3	9.44
Carbon, organic, sus	mg/L	2.1	.47	.38	5.5	1.3	1.3	.85	.52
Absorbance, UV, 254 nm, fil	units per centimeter	.49	.45	.68	.28	.55	.32	.48	.38
Absorbance, UV, 280 nm, fil	units per centimeter	.35	.34	.50	.21	.41	.22	.36	.28

Table 6. Trace-element concentrations in streams in the study area, Calhoun County, Michigan.

[All concentrations are in micrograms per liter; <, less than symbol used when no analyte was detected; *, a Michigan Department of Environmental Quality Standard for Aquatic Life has been established for this analyte; E, estimated value; M, presence verified, but not quantified; reporting-limit method for all analytes was laboratory reporting level (LRL)]

	Pine Creek at O Drive South 04096890				Unnamed Tributary to Pine Creek 04096891	Athens & Indian Creek Drain 04096894		
Trace element	**10/04/00**	**4/12/01**	**5/30/01**	**5/28/03**	**4/12/01**	**10/04/00**	**5/30/01**	**5/28/03**
Aluminum	26	10	11	4	10	9	30	10
Antimony	.1	.1	<.05	<.30	.09	.06	<.05	<.30
Arsenic *	E2	<2	3	3	<2	E1	E2	E2
Barium	41	40	36	54	37	35	49	58
Beryllium	<.06	<.06	<.06	<.06	<.06	<.06	<.06	<.06
Cadmium *	.07	E.03	<.04	<.04	.05	<.04	E.03	E.02
Chromium *	<.8	<.8	E.5	<.8	<.8	<.8	E.5	<.8
Cobalt	.29	.21	.16	.27	.21	.21	.31	.39
Copper *	1.9	1.1	.7	.6	.8	1.3	1.2	1.2
Iron	172	210	273	113	356	173	225	164
Lead	E.07	<.08	E.07	<.08	E.07	E.04	E.06	<.08
Manganese	50.3	63.4	47.1	130	104	89.6	60.1	46.3
Molybdenum	.7	.6	.5	.6	.5	.4	.9	1
Nickel *	1.7	.52	<.06	2.74	.22	1.08	.96	3.79
Selenium *	<2	<2	<2	<3	<2	<2	<2	<3
Silver	<1	<1	<1	<.20	<1	<1	<1	<.20
Uranium	.41	.45	.28	.5	.24	.24	.62	.9
Zinc *	5	2	1	M	2	3	3	3

with hardness concentrations reported as calcium carbonate exceeding 180 mg/L. Concentrations of calcium, magnesium, chloride, and dissolved solids (residue on evaporation) may seem high for surface waters, but they are typical of the area. The relatively high concentrations are probably the result of coarse-grained glacial sediment that predominates in most of the Pine Creek drainage basin (fig.4). Much of this coarse-grained sediment was transported from source areas, including outcrops in the northern part of the Lower Peninsula of Michigan. For comparison, the 17-year averages for samples at the St. Joseph River at Niles (USGS station 04101500), downstream in the basin, are calcium, 70 mg/L; magnesium, 20 mg/L; chloride 23.5, mg/L; and dissolved solids, 326 mg/L.

In the current study, there were 68 detections of 17 pesticides, degradates, and caffeine. Atrazine and metolachlor were detected in all surface-water samples, and the atrazine degradate deethylatrazine was detected in all samples from Pine Creek and Athens & Indian Creek Drain. Another atrazine degradate (2-hydroxy-atrazine, or OIET) was detected five of the six times it was included in the analyses. The May 30, 2001, sample from Athens & Indian Creek Drain had relatively higher concentrations of acetochlor, atrazine, CIAT (deethylatrazine), and diuron than all other sampling sites, including atrazine of 1.25 µg/L. The next highest concentration of atrazine (0.26 µg/L) was collected from Pine Creek on the same day. Spring rainfall and runoff from fields prior to May 30, 2001, may have led to the high concentrations of pesticides in samples from that day. The 17 pesticides, degradates, and caffeine that were detected in the surface-water samples are listed in table 9 with their chemical family, CAS number, and general use.

Results of sampling for mercury in Pine Creek and Athens & Indian Creek Drain are summarized in table 8. No notable or unusually high concentrations of the species analyzed for (total, methyl, and particulate) were found and the results are typical of surface-water bodies throughout the Midwest that are relatively unaffected by industrial deposition (J.F. DeWild, U.S. Geological Survey Wisconsin Water Science Center Mercury Laboratory, written commun., 2004). Organic complexes, such as methyl mercury, can be produced in oxygen-poor environments including wetlands (Hem, 1985) similar to those found along Pine Creek. The complexes, which

Table 7. Pesticide and caffeine detections in streams in the study area, Calhoun County, Michigan.

[All concentrations are in micrograms per liter; <, less than; E, estimated value; -, no analysis; --, analysis not available; shaded values are detected concentrations; Pine Creek at O Drive South, 04096890; Unnamed Tributary to Pine Creek, 04096891; Athens & Indian Creek Drain, 04096894; LRL, laboratory reporting level, MRL, minimum reporting level]

Site	Sample date	2,4-D	3,4-Di-chloro-aniline	Aceto-chlor	Aldi-carb sulfone	Atra-zine	Caf-feine	Chloro diaminos-triazine	Deethyl atrazine [CIAT]	Diuron	2-Hydroxy-atrazine (OIET)	Imaza-quin	Imaze-thapyr	Metola-chlor	Prome-ton	Sima-zine	Trial-late	Triclo-pyr
		Reporting limit and method																
		0.0218 MRL	0.0045 MRL	0.006 LRL	0.04 MRL	0.009 MRL	0.0096 MRL	0.01 MRL	0.006 LRL	0.015 MRL	0.008 MRL	0.016 MRL	0.017 MRL	0.013 LRL	0.005 LRL	0.005 LRL	0.002 LRL	0.0224 MRL
04096890	10/04/00	<0.11	-	0.010	<0.26	0.12	-	-	E.168	<0.049	-	-	-	0.038	<0.015	<0.011	<0.002	<0.070
	04/12/01	<.11	-	<.004	<.2	.012	-	-	E.007	.060	-	-	-	.035	<.015	E.007	<.002	<.070
	05/30/01	<.11	-	.044	<.20	.256	-	-	E.037	<.056	-	-	-	.064	<.015	<.011	<.002	<.070
	05/28/03	E.018	E.004	.008	<.02	.022	<0.010	<0.01	E.010	.052	E.027	<0.016	<0.017	.020	E.004	<.005	<.002	<.022
	06/17/03	<.022	.006	.008	<.02	.046	<.010	E.007	E.014	.019	E.025	<.016	<.017	.032	<.015	E.004	.003	<.022
	07/17/03	<.022	E.004	<.006	E.004	.016	.012	<.01	E.006	<.015	E.031	<.016	E.012	.026	<.015	<.005	<.002	<.022
	08/20/03	<.022	-	<.006	<.02	E.006	<.010	<.01	E.005	<.015	<.008	<.016	<.017	.024	E.005	<.005	<.002	<.022
	09/10/03	<.022	-	<.006	<.02	E.006	<.010	E.004	E.005	<.015	E.022	<.016	E.021	.019	<.15	<.005	<.002	<.022
04096891	04/12/01	<.11	-	<.004	<.21	E.006	-	-	<.006	<.056	-	-	-	.014	<.015	<.011	<.002	<.070
04096894	10/04/00	<.11	-	<.004	<.26	E.006	-	-	E.007	<.049	-	-	-	.022	<.015	<.011	<.002	<.070
	05/30/01	<.11	-	.245	<.20	1.25	-	-	E.150	<.13	-	-	-	E.012	<.015	<.011	<.002	<.070
	05/28/03	.026	<.004	.020	<.02	.093	<.010	<.01	E.041	<.015	E.068	E.007	<.017	E.011	<.015	.017	<.002	.252

are concentrated in aquatic food chains including fish, can be produced by methane-generating bacteria in contact with elemental mercury (Wood and others, 1968).

USEPA primary and secondary drinking-water standards (*www.epa.gov/safewater*) are often referenced in studies of surface-water quality, even though the water will likely never be used for drinking. The tribe does not currently use surface water for drinking water, and it is probably not used for that purpose by adjacent landowners. Surface water will probably not be used for drinking water in the near future because a sufficient quantity of good-quality, potable water is available in the shallow unconsolidated aquifer to supply single-family residences and the NHBP Tribal Office.

The iron concentration of 356 µg/L in the April 12, 2001, sample from the unnamed tributary exceeded the USEPA Secondary Maximum Contaminant Level (SMCL) of 300 µg/L. Manganese concentrations exceeded the USEPA SMCL of 50 µg/L in six of the eight samples. The other two manganese concentrations were within 4 µg/L of the SMCL. Nitrate and nitrite concentrations are below USEPA MCL, but are still high in samples from Pine Creek and Athens & Indian Creek Drain. Nitrate and nitrite concentrations in five of seven samples from Pine Creek and Athens & Indian Creek Drain exceed the 1993–98 USGS National Water-Quality Assessment (NAWQA) median concentration of 0.71 mg/L for streams throughout the United States (McPherson and others, 2000).

Concentrations of major elements and trace elements were also compared to State of Michigan standards for general water quality and the protection of aquatic and wildlife (State of Michigan, 2003). These standards are probably more applicable than USEPA MCLs or SMCLs to nonpotable waters like the streams in the study area. None of the sampled analytes exceeded these standards.

Tribal Water-Quality Monitoring

From 2000 to 2003, tribal environmental staff and students used a multiparameter probe to measure physical properties of surface water from the three USGS sampling sites. Tribal staff also measured the same physical properties at two additional downstream sites on Pine Creek and Athens & Indian Creek Drain and test well 1 at the Fuller Property, but those data are not included in the current report because USGS

Table 8. Streamflow, total mercury, methyl mercury, and particulate mercury in streams in the study area, Calhoun County, Michigan.

Site	Date	Streamflow (ft^3/s)	Total mercury-filtered	Methyl mercury-filtered	Particulate mercury
04096890	7/30/2003	5.38	1.07	0.24	0.256
04096894	7/30/2003	.05	.93	.07	.247

did not sample at those sites. Data collection began in April or May and ended in October each year. Physical properties measured were water temperature, dissolved-oxygen concentration, specific conductance, and pH. Multiple measurements were made at each site, but USGS protocol was not followed. Parts of the data are included in this report to show general, seasonal trends only; the data were not quality assured by USGS.

At each monitoring site, maximum water temperature was recorded in July, and minimum water temperature was recorded in April and November, reflecting seasonal variations and lag times. Many forms of aquatic life experience mortality when subjected to high-temperature water for time periods as short as 24 hours. Extreme variations in dissolved-oxygen concentrations can also harm aquatic life because of excessive biochemical oxygen demand (BOD). Decreases in dissolved oxygen to less than 3 mg/L in water can be harmful or lethal to many desirable species of aquatic life. At each monitoring site, specific conductance tended to be highest in the late spring and summer during periods of no to low runoff and low streamflow and lowest during the spring, associated with snowmelts and periods of high runoff and high streamflow. Fluctuations in pH may take place because of natural processes, such as the oxidation of ferrous iron or photosynthesis. Oxygenated waters dissolve ferrous iron, reducing the pH. With photosynthesis, aquatic organisms take up carbon dioxide during daylight hours and then release it at night. Where this take up and release occurs, maximum daylight pH may reach or exceed 9.0.

Physical properties of Pine Creek at O Drive and Athens & Indian Creek Drain were measured periodically from 2000 through 2003 at USGS sites 04096890 and 04096894, respectively. Physical properties of the unnamed tributary to Pine Creek were measured periodically from 2000 through 2002 at USGS site 04096891. No data were collected from site 04096891 in 2003 because of backwater and flooding caused by downstream beaver dams and pumping equipment and activities related to irrigation of surrounding land. Tribal measurements of minimum, maximum, and mean water

Table 9. Pesticides, degradates, and caffeine detected in streams in the study area, Calhoun County, Michigan.

[CAS, Chemical Abstracts Service]

Constituent	Chemical family	CAS number	General use
2,4-D	Phenoxy compound	94-75-7	Herbicide
3,4 Dichloroaniline	Dicarboximide	95-76-1	Fungicide
Acetochlor	Acetimide	34256-82-1	Herbicide
Aldicarb sulfone	Carbamate	1646-88-4	Degradate of aldicarb (insecticide)
Atrazine	Triazine	1912-24-9	Herbicide
Caffeine	Alkaloid	58-08-2	Beverages, diuretic
Chloro diamino-s-triazine	Triazine	3397-62-4	Degradate of atrazine (herbicide)
Deethylatrazine (CIAT)	Triazine	6190-65-4	Degradate of atrazine (herbicide)
Diuron	Substituted urea	330-54-1	Herbicide
2-Hydroxy-atrazine (OIET)	Triazine	2163-68-6	Degradate of atrazine (herbicide)
Imazaquin	Imidazole compound	81335-37-7	Herbicide
Imazethapyr	Imidazole compound	81335-77-5	Herbicide
Metolachlor	Chloroacetanilide	51218-45-2	Herbicide
Prometon	Triazine	1610-18-0	Herbicide
Simazine	Triazine	122-34-9	Herbicide
Triallate	Thiocarbamate	2303-17-5	Herbicide
Triclopyr	Pyridine	69633-04-1	Herbicide

temperature, dissolved-oxygen concentration, and specific conductance; and minimum, maximum, and median pH, for the sampling period are summarized in table 10.

SUMMARY

The Nottawaseppi Huron Band of Potawatomi (NHBP) Indians is concerned about the water quality and quantity in streams in and around tribal lands and of underlying shallow ground water. The traditional NHBP Reservation is located about 12 mi south of Battle Creek and about 2 mi northwest of the Village of Athens, Michigan. The reservation and satellite property comprise about 275 acres of a 6.5 mi^2 study area. Land use in the study area is typical of many areas in southern Lower Michigan, comprising about 65 percent agricultural land, 20 percent forested land, and 14 percent wetland. The tribe recognizes that Pine Creek and its associated tributaries provide an appreciable resource for maintaining subsistence needs for tribal members. The investigation described in this report was a cooperative effort between NHBP and U.S. Geological Survey (USGS), with funding from U.S. Environmental Protection Agency (USEPA), Bureau of Indian Affairs (BIA), and USGS. The tribe has been measuring physical properties of streams on and near the reservation and in at least one test well located on tribal property since 2000. In 2002, the tribe developed plans to sample streambed sediment and plant tissue in the future.

Prior to this investigation, little was known about the hydrology of the study area. The tribe wanted to establish a database that included streamflow, stage, and water quality of local streams, and quality of ground water from wells belonging to the tribe and its members. The tribe, which is concerned about the effects of long-term agricultural activity and increasing numbers of single-family dwellings being constructed within the drainage basin, wants to plan its own expansion in a way to minimize the effects on water resources.

Designing and implementing a comprehensive water-resources plan that protects tribal water resources could not be started until baseline surface- and ground-water measurements were made and compiled and water-quality data collected and analyzed.

The near-surface geology of the NHBP Reservation consists of unconsolidated Holocene and Pleistocene alluvial deposits and Pleistocene glaciofluvial deposits, underlain by Mississippian Coldwater Shale. Thickness of unconsolidated deposits varies dramatically across the study area, with thickest deposits near stream courses. Drillers' logs of wells indicate that the Coldwater Shale, or broken and fractured pieces of the Coldwater Shale, can be found as close as 23 ft below the surface, whereas unconsolidated deposits as thick as 200 ft are found

Table 10. Physical properties measured by Nottawaseppi Band of Huron Potawatomi Indian Tribe of streams crossing the reservation, Calhoun County, Michigan. Data were collected periodically during the growing season from April 2001 through September 30, 2003, except at site 04096891, where data was collected from January 2001 through September 2002.

[°C, degrees Celsius;--, no data; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C]

	04096890				04096891				04096894			
	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µS/cm)	pH (Standard units)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µS/cm)	pH (Standard units)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µS/cm)	pH (Standard units)
Mean	17.8	5.8	470	--	15.6	6.6	459	--	16.7	7.1	502	--
Median	--	--	--	7.5	--	--	--	7.4	--	--	--	7.7
Minimum	6.4	1.0	357	6.8	4.4	2.9	358	7.0	6.1	2.9	374	6.8
Date	--	July 24, 2001	May 25, 2001	Nov. 5, 2001	--	July 24, 2001	June 6, 2001	May 25, 2001	--	Oct. 2, 2002	Aug. 27, 2001	Aug. 26, 2002
Maximum	24.2	13.0	566	8.5	23.3	9.7	575	8.4	22.2	12.5	559	8.5
Date	--	Apr. 4, 2001	June 23, 2003	Oct. 3, 2002	--	Apr. 4, 2001	Oct. 2, 2002	Sept. 23, 2002	--	Apr. 4, 2001	Oct. 14, 2002	Sept. 16, 2002

near Nottawa Creek (Fleis and Vandenbrink Engineering, 2000). Unconsolidated deposits are typically in the range of 50 to 85 ft thick near the reservation. Glacial deposits are thought to be the sole source of potable water available to the NHBP Reservation and most other residents in the study area, because the Coldwater Shale is typically unsuitable as an aquifer, because of either extremely low yield or poor water quality.

The NHBP Reservation lies entirely within the St. Joseph River Basin, which drains to Lake Michigan. Three tributaries of Pine Creek or Nottawa Creek cross the reservation. The tributaries are Pine Creek, with headwaters north of the reservation; a county drain locally known as Athens & Indian Creek Drain, which drains farmland northwest of the reservation; and an unnamed creek that flows from the west into Pine Creek after crossing the Fuller Property about 1.5 mi north of the reservation. The USGS measured streamflow and installed staff gages tied into local datum on Pine Creek, Athens & Indian Creek Drain, and the unnamed tributary to Pine Creek, and collected water-quality samples from the sites under a variety of flow regimes and times during the agricultural cycle. Stage-streamflow rating curves were constructed for Pine Creek and Athens & Indian Creek Drain after a number of streamflow measurements and a thorough basin analysis was complete. Streamflow for Pine Creek near Athens was estimated for the period from May 2000 through September 2003.

USGS collected water-quality samples at Pine Creek near Athens, Athens & Indian Creek Drain, and an unnamed tributary to Pine Creek during the period from October 2000 through September 2003. Physical properties were measured, and the streams were sampled for major ions, nutrients, trace elements, caffeine, and pesticides and their breakdown products (degradates). Complementing the USGS study, the tribe periodically measured physical properties at various surface-water sites near the reservation (including the three USGS sites). Surface water at the three sites can be classified as hard, with hardness concentrations reported as calcium carbonate exceeding 180 mg/L. Atrazine and metolachlor were detected in all surface-water samples, and the atrazine degradate deethylatrazine was detected in all samples from Pine Creek and Athens & Indian Creek Drain. Another atrazine degradate, 2-hydroxyatrazine, or OIET, was detected five of the six times it was included in the analyses suite. A single sample collected from Athens & Indian Creek Drain in May 2001 had higher concentrations of acetochlor, atrazine, CIAT (deethylatrazine), and diuron than the other sampling sites did during the study. Analysis for total- and methyl-mercury was completed on samples collected at Pine Creek and Athens & Indian Creek Drain. Results of the mercury analyses were similar to those of other streams in the Midwest that are unaffected by large-scale mercury contamination. None of the surface-water sites had major ion or common trace element concentrations that exceeded Michigan Department of Environmental Quality Standards for non-potable surface water.

USGS also collected ground-water samples from seven wells on or adjacent to the traditional reservation in 2003. Three of the wells were sampled multiple times in order to document any chemical changes that might have occurred because of aquifer recharge.

Samples were analyzed for nearly 200 pesticides and degradates and caffeine. There were five detections of four pesticides or degradates, but none of the detected pesticides and degradates are included in the U.S. Environmental Protection Agency drinking-water standards. The remaining analytes were below laboratory reporting levels.

The USGS study provides a database of baseline stream stage and flow, and surface- and ground-water-quality data that tribal planners and environmental staff can use to help design a comprehensive water-resources plan that will complement their development plan.

Acknowledgments

Doug Craven and David Jones, previous and current NHBP Environmental Directors, respectively, provided invaluable assistance throughout the project. Dan Green and Ashley Cordi, previous and current NHBP Environmental Specialists, respectively, periodically measured physical properties at the surface-water sites and assisted with fieldwork throughout the project. Many NHBP tribal officials and members also played a role in the study, providing access to sites throughout the reservation and granting access to homes and domestic-supply wells that were sampled for the ground-water part of this study. USGS employees that assisted the authors included Tom Behrendt, Brian Heissenberger, Rick Hubbell, Glenn Lansky, Ron Leuvoy, Tom Morgan, Dan Obenauer, and Chuck Whited.

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APPENDIX: Drillers' Logs of Nottawaseppi Huron Band of Potawatomi Indian public-water-supply and test wells

GEOLOGICAL SURVEY SAMPLE No. 1

Old Community Center Well

WATER WELL RECORD
ACT 294 PA 1965

MICHIGAN DEPARTMENT OF PUBLIC HEALTH

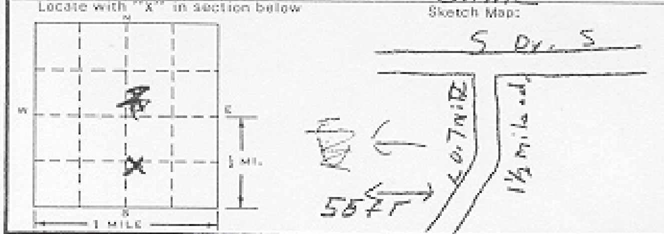
1 LOCATION OF WELL

County: Calhoun
Township Name: Athens
Fraction: SW SW SE
Section Number: 20
Town Number: 4 S.
Range Number: 8 W.

Distance And Direction from Road Intersections: About 0.7 mile South of S. Drive S and About 55 ft. West of 1½ mile rd.

Street address & City of Well Location: Same

Locate with "X" in section below — Sketch Map:



3 OWNER OF WELL: Huron Potawatomi, Inc.
Address: 1½ Mile rd. R#1
Athens, Mich. Fulton

4 WELL DEPTH: (completed) 50 ft. Date of Completion 1-5-78

5 ☐ Cable tool ☐ Rotary ☐ Driven ☐ Dug
☐ Hollow rod ☒ Jetted ☐ Bored ☐

6 USE: ☐ Domestic ☒ Public Supply ☐ Industry
☐ Irrigation ☐ Air Conditioning ☐ Commercial
☐ Test Well ☐

7 CASING: Threaded ☒ Welded ☐
2 in. to 46½ ft. Depth
in. to ft. Depth
Height: Above/Below Surface 1 ft.
Weight 3.68 lbs./ft.
Drive Shoe? Yes ☒ No ☐

8 SCREEN:
Type: Blue Devil Dia.: 1¼"
Slot/Gauze 10 Length 42"
Set between 46½ ft. and 50 ft.
Fittings: Drive couplings

9 STATIC WATER LEVEL
27 ft. below land surface

10 PUMPING LEVEL below land surface
27 ft. after ½ hrs. pumping 20 g.p.m.
ft. after hrs. pumping g.p.m.

11 WATER QUALITY in Parts Per Million:
Iron (Fe) Chlorides (Cl)
Hardness Other

12 WELL HEAD COMPLETION: ☐ In Approved Pit
☐ Pitless Adapter ☒ 12" Above Grade

13 Well Grouted? ☒ Yes ☐ No
☐ Neat Cement ☐ Bentonite ☒ Slurry
Depth: From ft. to ft.

14 Nearest Source of possible contamination
feet Direction Type
Well disinfected upon completion ☒ Yes ☐ No

15 PUMP: ☐ Not installed
Manufacturer's Name Gould
Model Number VT07 HP ¾ Volts
Length of Drop Pipe 42 ft. capacity 12 G.P.M.
Type: ☐ Submersible
☒ Jet ☐ Reciprocating

2 FORMATION

FORMATION	THICKNESS OF STRATUM	DEPTH TO BOTTOM OF STRATUM
Top soil	2	2
Sand, gravel	14	16
Clay, brownish, some gravel	4	20
Clay, gray	9	29
Sand, fine powdery	11	40
Clay, gray	2	42
Gravel, very coarse, Sand coarse Water	8	50

Coarse Gravel + Sand

USE A 2ND SHEET IF NEEDED

16 Remarks, elevation, source of data, etc.
Well Permit # 0030

RECEIVED
JAN 12 1978

17 WATER WELL CONTRACTOR'S CERTIFICATION:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
L+D Well Drilling — REGISTERED BUSINESS NAME
1560 — REGISTRATION NO.
Address 1418 Stalwart Kal. Mi.
Signed Leonard Born — AUTHORIZED REPRESENTATIVE
Date 1-5-78

067d 100M (Rev. 12-68)

Calhoun County Health Department

LOCAL HEALTH DEPT. COPY

05/09/01 10:32 FAX 16169646635 K W D INC 02

New Community Center Well

TAX NO. MICHIGAN WATER WELL AND PUMP RECORD Permit No. 5 9 4 8

1 Location of Well

County	Township Name	Fraction	Section Number	Town Number	Range Number
CALHOUN	ATHENS	SE 1/4 NW 1/4 SE 1/4	20	4-S N/S	8-W E/W

Distance and Direction From Road Intersection

2221 1 1/2 MILE RD

Street Address and City of Well Location

3 Owner of Well HURON POTAWATOMIE

Address 2221 1 1/2 MILE RD
MI

Address Same as Well Location? Yes

Sketch Map

4 Well Depth (Completed) 62 ft. | Date of Completion 04/19/00 New Well

5 Drilling Method MUD ROTARY

6 Proposed Use DOMESTIC

Water Bearing Gravel

12

FORMATION DESCRIPTION	Thickness of Stratum	Depth to Bottom of Stratum
FINE GRAVEL AND SAND	6	5
SOFT BROWN CLAY SAND	6	12
MEDIUM GRAVEL SAND	6	18
BROWN CLAY	3	21
SAND	2	23
BROWN CLAY	2	25
SAND	7	32
BROWN CLAY	2	34
SAND	2	36
GREY CLAY	4	40
GRAVEL AND SAND	12	52
WATER BEARING GRAVEL	10	62

7 Casing 5" PVC | Height Above
5 in. to 52 ft. depth | Surface 1 ft.
in. to ft. depth | Weight 3LB lbs./ft.
Bore Hole Diameter
10 in. to 52 ft. depth | Drive Shoe No
in. to ft. depth | Shale Packer Yes

8 Screen Gravel-packed? No
Type STAINLESS STEEL Diameter 5"
Slot/Gauze 25 SLOT Length 10'
Set Between 52 ft. and 62 ft.
Fittings K-PACKER 1.00 Blank ft. above screen

9 Static Water Level 20 Ft. Below Land Surface Flo

10 Pumping Level Below Land Surface
40 ft. after 1 hrs. pumping at 30+ G.P.M.
ft. after hrs. pumping at G.P.M.
Using AIR

11 Well Head Completion 12"ABOVE GRADE

12 Well Grouted? Yes From 0 to 52 ft.
BENTONITE
No. of bags 5 Additives 5 BGS BENTONITE

13 Nearest Source of Possible Contamination
SEPTIC Distance 75 ft. Direction SW
Distance ft. Direction

15 Abandoned well plugged? No
Casing Diameter in. Depth ft.
Casing removed? No

14 Pump Installed Pump Installation Only? No
Manufacturer's Name MC DONALD
Model Number 2101OP2 HP 1 Volts 230
Length of Drop Pipe 40 ft. Capacity 10 G.P.M.
Type SUBMERSIBLE Jet
Pressure tank:
Manufacturer's Name ELBI
Pressure Tank Model DV-200 Capacity 18 gal.

16 Remarks, elevation, source of data, etc.
NOTTAWASEPPI HURN POTAWATIMIE JOB

17 Drilling machine operator:
Employee
Name RICK FREY

Authority: Act 368 PA 1978
Completion: Required.
Penalty: Conviction of violation of any provision is a misdemeanor.

18 Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Registered business name: KATZ WELL DRILLING INC.
Registration number: 13-1593
Address: 1479 EAST MICHIGAN AVE, BATTLE CREEK, MI 49-017
Signed: ____________________ Date____________
(Authorized representative)

05/09/01 10:32 FAX 16169646635 K W D INC 003

TW1

TAX NO. MICHIGAN WATER WELL AND PUMP RECORD Permit No. 5 9 4 8

1 Location of Well

County	Township Name	Fraction	Section Number	Town Number	Range Number
CALHOUN	ATHENS	NE 1/4 NE 1/4 SW 1/4	17	4-S N/S	8-W E/W

Distance and Direction From Road Intersection
1/8 MI W OF 1 1/2 MILE RD 400' SO OF Q DR S

Q DR S

Street Address and City of Well Location

3 Owner of Well HURON POTAWATOMI
Address 2221 1 1/2 MILE RD
MI
Address Same as Well Location? No

Sketch Map

4 Well Depth (Completed) 67 ft. | Date of Completion 06/02/00 | New Well

5 Drilling Method MUD ROTARY

6 Proposed Use TESTING

2 FORMATION DESCRIPTION

FORMATION DESCRIPTION	Thickness of Stratum	Depth to Bottom of Stratum
FINE GRAVEL AND SAND	9	9
BROWN CLAY	4	13
FINE GRAVEL AND SAND	7	20
MEDIUM GRAVEL SAND	15	35
SOFT BROWN CLAY SAND	2	37
FINE GRAVEL AND SAND	18	55
BLACK CLAY	1	56
BROWN CLAY	3	59
WATER BEARING SAND	8	67
GRAVEL AND SAND	5	72
GREY CLAY	3	75
HARD SANDSTONE STONES	6	81
SAND	4	85
SHALE	5	90

Gravel + Sand

85'

7 Casing 5" PVC | Height Above Surface 1 ft.
5 in. to 57 ft. depth | Weight 3LB lbs./ft.
in. to ft. depth
Bore Hole Diameter
9 in. to 57 ft. depth | Drive Shoe No
in. to ft. depth | Shale Packer Yes

8 Screen Gravel-packed? No
Type STAINLESS STEEL Diameter 4"
Slot/Gauze 20 SLOT Length 10'
Set Between 57 ft. and 67 ft.
Fittings K-PACKER 1.00 Blank ft. above screen

9 Static Water Level 4 ft. Below Land Surface Flo

10 Pumping Level Below Land Surface
55 ft. after 1 hrs. pumping at 20 G.P.M.
ft. after hrs. pumping at G.P.M.
Using AIR

11 Well Head Completion 12"ABOVE GRADE

12 Well Grouted? Yes From 0 to 57 ft.
BENTONITE
No. of bags 5 Additives 5 BGS BENTONITE

13 Nearest Source of Possible Contamination
Distance ft. Direction
Distance ft. Direction

14 Pump Not Installed

15 Abandoned well plugged? No
Casing Diameter in. Depth ft.
Casing removed? No

16 Remarks, elevation, source of data, etc.
59-67 STICKY SAND

17 Drilling machine operator:
Employee
Name RICK FREY
Authority: Act 368 PA 1978
Completion: Required.
Penalty: Conviction of violation of any provision is a misdemeanor.

18 Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Registered business name: KATZ WELL DRILLING INC.
Registration number: 13-1593
Address: 1479 EAST MICHIGAN AVE, BATTLE CREEK, MI 49-017
Signed: __________ Date__________

TW2 "HOLE 2"

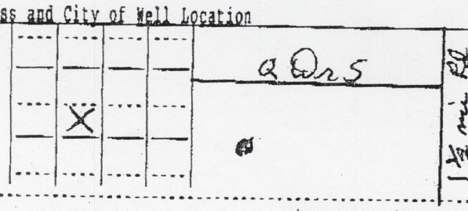
TAX NO. 06667-02KJ01 **MICHIGAN WATER WELL AND PUMP RECORD** Permit No.

1 Location of Well County	Township Name	Fraction	Section Number	Town Number	Range Number
CALHOUN	ATHENS	NE 1/4 NE 1/4 NW 1/4	17	T4S N/S	R8W E/W

Distance and Direction From Road Intersection
1/10TH MILE SOUTH OF Q DRIVE
3/10THS MILE WEST OF 1 1/2 MILE RD
Q DRIVE
ATHENS
Street Address and City of Well Location

3 Owner of Well POKAGON BAND OF POTAWATOM
Address 901 SPRUCE ST
DOWAGIAC MI 49047-
Address Same as Well Location? No

Sketch Map



4 Well Depth (Completed) 340 ft. | Date of Completion 11/22/02 New Well

5 Drilling Method ROTARY

6 Proposed Use TEST WELL

2 FORMATION DESCRIPTION

FORMATION DESCRIPTION	Thickness of Stratum	Depth to Bottom of Stratum
BROWN SAND LOAM	9	9
GRAVEL STONES	5	14
GRAY CLAY	8	22
GRAVEL GRAY CLAY	3	25
RED SAND & GRAVEL	4	29
BROWN SAND CLAY	7	36
SAND	4	40
GRAY CLAY	3	43
SAND & GRAVEL	33	76
GRAY CLAY STONES	2	83
SOFT GRAY SHALE	9	92
HARD SANDSTONE SAND	10	102
SOFT GRAY SHALE	60	162
GRAY SHALE LIMESTONE	19	181
BLACK SHALE	102	283
GRAY SHALE SANDSTONE LIMESTONE	53	336
BLACK SHALE	4	340

7 Casing PVC
5 in. to 96 ft. depth
in. to ft. depth
Bore Hole Diameter
8 3/4 in. to 94.5 ft. depth
4 1/2 in. to 340 ft. depth
Height Above Surface 1.5 ft.
Weight 2.87 lbs./ft.
Drive Shoe No
Shale Packer No

8 Screen Not Installed Gravel-packed? No

9 Static Water Level 8 Ft. Below Land Surface Flo

10 Pumping Level Below Land Surface
340 ft. after hrs. pumping at 15 G.P.M.
ft. after hrs. pumping at G.P.M.
Using

11 Well Head Completion 1.5'

12 Well Grouted? Yes From 94.5 to 0 ft.
NEAT CEMENT
No. of bags 20 Additives

13 Nearest Source of Possible Contamination
SEPTIC TANK Distance 1400+ ft. Direction W
Distance ft. Direction

14 Pump Not Installed

15 Abandoned well plugged? No
Casing Diameter in. Depth ft.
Casing removed? No

16 Remarks, elevation, source of data, etc.
POKAGON BAND OF POTAWATOMI INDIANS

17 Drilling machine operator:
Employee
Name R HEILER

Authority: Act 368 PA 1978
Completion: Required.
Penalty: Conviction of violation of any provision is a misdemeanor.
IMPORTANT: File with deed.

18 Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Registered business name: HART WELL DRILLING CO.
Registration number: 1686
Address: 1154 SOUTH JEFFERSON, MASON, MI 48854
Signed: David W. Hart Date 11/29/02
(Authorized representative)

WELL OWNER

PAGE 03

TW3 "HOLE 3"

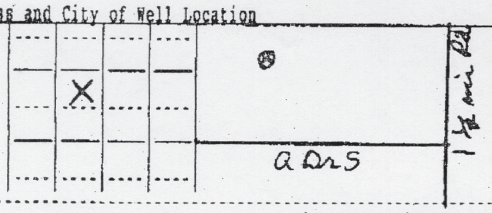
TAX NO. 06666-02KR01 **MICHIGAN WATER WELL AND PUMP RECORD** Permit No.

1 Location of Well County	Township Name	Fraction	Section Number	Town Number	Range Number
CALHOUN	ATHENS	SE 1/4 NW 1/4 NW 1/4	17	T4S N/S	R8W E/W

Distance and Direction From Road Intersection
2/10THS MILE NORTH OF Q DRIVE
3/10THS MILE WEST OF 1 1/2 MILE RD
Q DRIVE
ATHENS
Street Address and City of Well Location

3 Owner of Well POKAGON BAND OF POTAWATOM
Address 901 SPRUCE ST
DOWAGIAC MI 49047-
Address Same as Well Location? No

Sketch Map



4 Well Depth (Completed) 78 ft. | Date of Completion 11/25/02 New Well

5 Drilling Method ROTARY

6 Proposed Use TEST WELL

2

FORMATION DESCRIPTION	Thickness of Stratum	Depth to Bottom of Stratum
TOPSOIL	2	2
BROWN SAND LOAM	2	4
SAND & GRAVEL	10	14
GRAY CLAY	8	22
SAND & GRAVEL	3	25
GRAY CLAY GRAVEL STRIPS	10	35
SAND COARSE GRAVEL	43	78

7 Casing PVC
5 in. to 71.6 ft. depth
in. to ft. depth
Bore Hole Diameter
8 3/4 in. to 69.5 ft. depth
in. to ft. depth
Height Above Surface 2 ft.
Weight 2.87 lbs./ft.
Drive Shoe No
Shale Packer No

8 Screen Gravel-packed? Yes
Type STAINLESS STEEL Diameter 4"
Slot/Gauze 18 Length 8.5
Set Between 69.6 ft. and 78 ft.
Fittings NIPPLE & PLUG 0.00 Blank ft. above screen
K-PACKER RISER

9 Static Water Level Ft. Below Land Surface Flo

10 Pumping Level Below Land Surface
ft. after hrs. pumping at G.P.M.
ft. after hrs. pumping at G.P.M.
Using

11 Well Head Completion 2' ABOVE GRADE

12 Well Grouted? Yes From 70 to 0 ft.
NEAT CEMENT
No. of bags 14 Additives

13 Nearest Source of Possible Contamination
SEPTIC TANK Distance 1500+ ft. Direction SW
Distance ft. Direction

14 Pump Not Installed

15 Abandoned well plugged? No
Casing Diameter in. Depth ft.
Casing removed? No

16 Remarks, elevation, source of data, etc.
POKAGON BAND OF POTAWATOMI INDIANS.

17 Drilling machine operator:
Employee
Name R HEILER
Authority: Act 368 PA 1978
Completion: Required.
Penalty: Conviction of violation of any provision is a misdemeanor.
IMPORTANT: File with deed.

18 Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Registered business name: HART WELL DRILLING CO.
Registration number: 1686
Address: 1254 SOUTH JEFFERSON, MASON, MI 48854
Signed: David W. Hart Date 11/29/02
(Authorized representative)

WELL OWNER

USGS

Weaver, Healey, and Sabin —**Water Resources on and near the Nottawaseppi Huron Band of Potawatomi Indian Tribal Lands, Calhoun County, Michigan, 2000-03**—Open-File Report 2004-1406